Bulletin

Ohio Agricultural Experiment Station

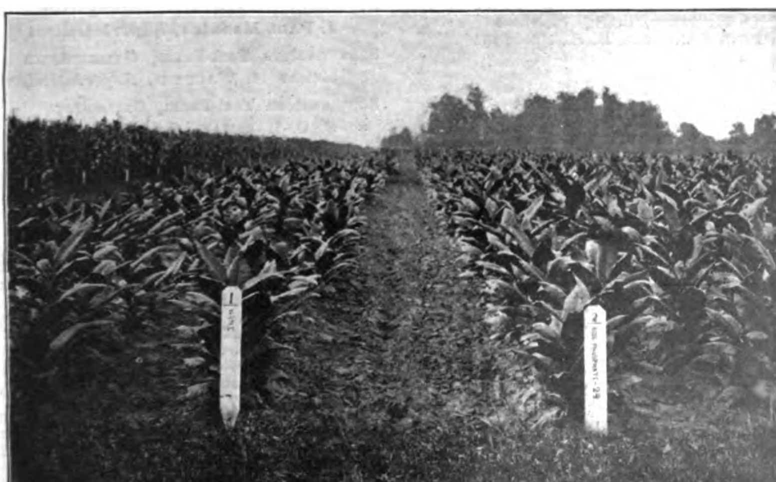
THE MAINTENANCE OF FERTILITY

FIELD EXPERIMENTS WITH FERTILIZERS AND MANURES ON TOBACCO, CORN, WHEAT AND CLOVER IN THE MIAMI VALLEY.

OHIO Agricultural Experiment Station.

WOOSTER, OHIO, U. S. A., AUGUST, 1909.

BULLETIN 206.



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BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 206. AUGUST, 1909

EXPERIMENTS WITH FERTILIZERS AND MANURE ON TOBACCO, CORN, WHEAT AND CLOVER IN THE MIAMI VALLEY

These experiments were begun in 1903 on tobacco, grown both continuously and in rotation with wheat and clover, and in 1904 and 1905 on corn and wheat, grown in a rotation of corn, wheat and clover. A description of the soil and the plan of the experiments with tobacco are given in Bulletin 161 of this Station, and a continuation of the work with tobacco up to 1905 is reported in Bulletin 172. The rotation of corn, wheat and clover is in part reported in Bulletin 182, and the statistics of all the crops up to 1906 are given in Bulletin 184.

I: FERTILIZERS AND MANURE ON TOBACCO GROWN IN ROTATION

The plan of fertilizing in the rotation of tobacco, wheat and clover is given in Table I and Diagrams I and II; the statistics of yield for the years 1907 and 1908 are given in Table II, and a general summary of the results for the entire period is given in Table III, in which the yields of tobacco are grouped in two 3-year periods, thus showing the cumulative effect of the fertilizers during the second period.

DIAGRAM I: ARRANGEMENT OF PLOTS IN TOBACCO-WHEAT-CLOVER ROTATION

Section A

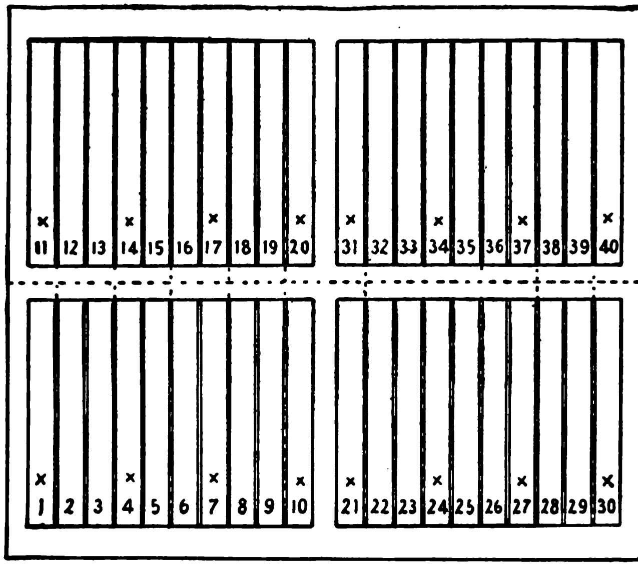

TABLE I: PLAN OF FERTILIZING TOBACCO GROWN IN ROTATION.

Plot No.	Fertilizing materials per acre (All applied to the tobacco crop)	Fertilizing elements per acre		
		Phos-phorus	Potas-sium	Nitro-gen
		Lbs.	Lbs.	Lb
1	None	..	..	..
2	Acid phosphate, 480 lbs.	30	..	..
3	Acid phosphate, 480 lbs.; muriate potash, 180 lbs.	30	75	..
4	None	..	..	..
5	Muriate potash, 180 lbs.; nitrate soda, 240 lbs.	..	75	38
6	Acid phosphate, 480 lbs.; nitrate soda, 240 lbs.	30	..	38
7	None	..	..	..
8	Acid phos., 480 lbs.; mur. potash, 180 lbs ; nit. soda, 240 lbs.	30	75	38
9	Acid phos., 480 lbs.; mur. potash, 300 lbs.; nit. soda, 240 lbs.	30	125	38
10	None	..	..	..
11	None	..	..	..
12	Acid phos., 480 lbs.; mur. potash, 120 lbs.; nit. soda, 240 lbs.	30	50	38
13	Acid phos., 720 lbs.; mur. potash, 180 lbs.; nit. soda, 240 lbs.	45	75	38
14	None	..	..	..
15	Acid phos., 480 lbs.; mur. potash, 180 lbs.; nit. soda, 360 lbs.	30	75	57
16	Acid phos., 480 lbs.; mur. potash, 180 lbs.; sulph. ammonia, 180 lbs.	30	75	38
17	None	..	..	..
18	Acid phos., 60 lbs.; Tankage (7-20) 670 lbs.; muriate potash, 180 lbs.	30	75	38
19	Acid phos., 320 lbs.; mur. potash, 180 lbs.; nit. soda, 240 lbs.	20	75	38
20	None	..	..	..
21	None	..	..	..
22	Acid phos., 480 lbs.; nitrate potash, 200 lbs.; nit. soda, 80 lbs.	30	75	38
23	Acid phos., 480 lbs.; sulphate potash, 190 lbs.; nit. soda, 240 lbs.	30	75	38
24	None	..	..	..
25	Acid phos., 480 lbs.; sul. potash, 190 lbs., nit. soda, 240 lbs.; lime 1000 lbs.	30	75	38
26	Acid phos., 480 lbs.; mur. potash. 180 lbs; nit soda, 240 lbs.; lime 1000 lbs.	30	75	38
27	None	..	..	..
28	Acid phos., 480 lbs.; mur. potash, 180 lbs.; sul. am., 180 lbs.; lime 1000 lbs.	30	75	38
29	Acid phos., 60 lbs.; tankage (7-20) 670 lbs.; mur. pot., 180 lbs.; lime 1000 lbs	30	75	38
30	None	..	..	..
31	None	..	..	..
32	Shed manure, untreated, 10 tons	..	..	..
33	Shed manure, untreated, 20 tons	..	..	..
34	None	..	..	..
35	Shed manure, phosphated, 10 tons	..	..	..
36	Yard manure, phosphated, 10 tons	..	..	..
37	None	..	..	..
38	Shed manure, untreated, 10 tons; lime, 1000 lbs.	..	..	..
39	Yard manure, untreated, 10 tons; lime, 1000 lbs.	..	..	..

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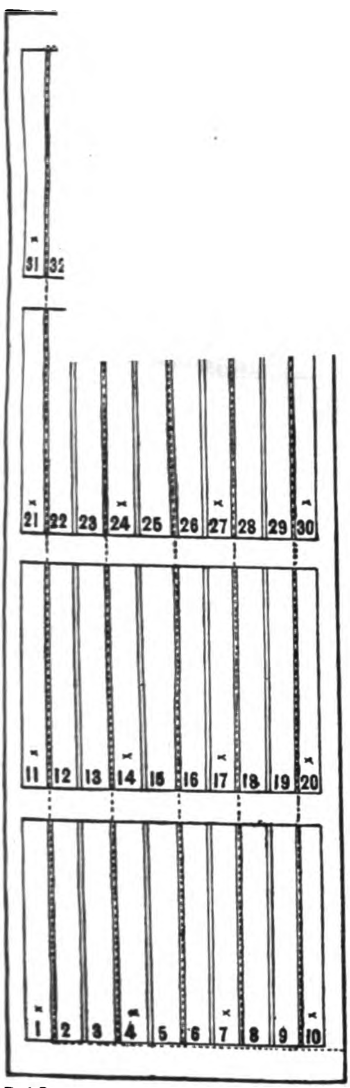


DIAGRAM II: Arrangement of plots in tobacco-wheat-clover rotation. Sections B and C.

feet wide by 136 feet long, containing ated by paths two feet wide and tile s are laid under alternate paths, make drains 36 feet apart. The plots are ged in blocks of ten plots each and in sections, A, B and C, of 40 plots each, licated by the diagrams, and every plot is left continuously untreated. The se due to treatment is calculated on the ption that if Plots 1 and 4, untreated, o yield 300 and 330 pounds respectively, aided yields of Plots 2 and 3 would bly have been 310 and 320 pounds.

ection A is located on a small farm of es, which had been owned separately rom the tract on which B and C are located before the land was leased by the Experiment Station.

In Table IV is given the average increase per acre for each crop over the entire period of the experiment with its value, rating tobacco at eight cents per pound for the wrapper and filler and one and one-half cent for the trash; wheat at 80 cents per bushel; straw at $2.00 per ton, and hay at $8.00. This table also shows the cost of the fertilizing, rating 14 percent acid phosphate at $16.00 per ton; muriate of potash at two and one-half cents per pound, and nitrate of soda at three cents, and estimating the cost of potassium in the sulphate as 20 percent greater than in the muriate. The cost of nitrogen is assumed to be the same in nitrate of soda, nitrate of potash and sulphate of ammonia. The tankage used in the test is computed at $28.00 per ton. Lime is figured at $6.00 per ton. No values are placed upon the manure, as the cost of manure varies for each farm and for different parts of the same farm, owing to the distance from the barn. The phosphated manure has been dusted with floats applied at the rate of 40 to 50 pounds per ton of manure, equivalent to one pound per 1000-pound animal per day.

TABLE II: TOBACCO-WHEAT-CLOVER ROTATION. STATISTICS OF YIELD FOR 1907 AND 1908

Plot	Tobacco						Wheat				Clover hay	
	1907			1908			1907		1908			
	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	Grain	Straw	Grain	Straw	1907	1908
No.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Bus.	Lbs.	Bus.	Lbs.	Lbs.	Lbs.
1	605	140	745	395	150	545	19.78	2,133	9.67	2,000	2,480	3,000
2	970	180	1,150	640	200	840	22.29	2,403	17.75	3,755	2,760	4,460
3	1,230	150	1,380	1,020	180	1,200	24.43	2,634	22.67	3,760	3,520	5,080
4	550	150	700	430	130	560	22.29	2,403	9.83	2,190	2,260	2,520
5	970	130	1,100	580	140	720	29.44	3,175	12.50	2,430	2,940	3,240
6	1,300	180	1,480	835	190	1,025	26.93	2,904	20.42	3,835	3,100	4,460
7	655	120	775	470	170	640	19.55	2,107	12.08	2,315	2,500	2,640
8	1,460	120	1,580	1,185	210	1,395	26.22	2,827	22.50	3,350	3,260	5,020
9	1,380	160	1,540	1,090	170	1,260	26.93	2,904	22.58	3,225	3,360	5,120
10	480	145	625	505	140	645	19.43	2,095	10.50	1,990	2,860	2,500
11	425	135	560	440	140	580	21.09	2,275	9.33	1,760	3,400	2,920
12	1,205	140	1,345	1,170	140	1,310	27.05	2,917	24.25	3,985	3,440	4,980
13	1,425	120	1,545	1,240	170	1,410	30.27	3,264	28.58	4,285	3,900	6,020
14	360	125	485	380	130	510	23.12	2,493	10.75	1,915	2,400	3,340
15	1,250	130	1,380	1,095	160	1,255	30.87	3,328	27.58	4,045	2,700	5,480
16	1,135	140	1,275	1,050	140	1,190	28.72	3,096	27.00	3,960	2,440	5,620
17	355	120	475	330	130	460	23.24	2,505	9.50	1,830	1,620	3,360
18	1,100	120	1,220	885	170	1,055	30.75	3,315	26.58	3,765	2,580	4,640
19	1,060	130	1,190	1,020	160	1,180	27.18	2,930	25.67	3,720	2,760	4,500
20	275	100	375	390	155	545	20.28	2,185	7.75	1,435	2,380	3,080
21	465	140	605	460	140	600	16.69	1,800	8.83	1,490	3,220	2,240
22	1,170	150	1,320	1,070	190	1,260	25.86	2,788	21.42	3,595	3,140	4,440
23	1,190	170	1,360	1,095	185	1,280	26.46	2,852	20.92	3,385	3,660	4,440
24	340	120	460	615	170	785	18.23	1,966	6.50	1,150	2,680	2,200
25	1,100	160	1,260	1,070	160	1,230	26.22	2,827	22.92	3,445	3,700	4,180
26	1,195	145	1,340	1,120	180	1,300	27.53	2,968	24.17	3,630	3,740	4,160
27	375	135	510	485	150	635	17.88	1,927	7.25	1,365	2,620	1,980
28	1,120	160	1,280	1,155	110	1,265	24.91	2,685	24.50	3,530	3,700	4,680
29	1,175	150	1,325	930	160	1,090	27.16	2,930	19.92	2,865	3,620	4,400
30	550	160	710	385	150	535	17.04	1,838	10.00	1,700	2,140	2,060
31	680	120	800	330	120	450	15.61	1,683	10.50	1,670	2,240	1,700
32	1,130	120	1,250	720	130	850	29.08	3,135	16.92	2,905	2,660	3,420
33	1,340	170	1,510	915	170	1,085	37.31	4,022	22.33	3,460	3,460	5,040
34	550	130	680	350	140	490	18.71	2,017	6.33	1,060	2,580	2,280
35	1,135	125	1,260	840	155	995	27.18	2,930	23.42	3,575	3,340	5,040
36	1,120	120	1,240	620	140	760	30.75	3,315	21.08	3,335	2,620	4,880
37	470	140	610	380	120	500	17.16	1,850	6.67	1,540	2,260	1,960
38	930	110	1,040	590	150	740	27.89	3,006	16.75	3,195	2,760	3,380
39	540	120	660	500	150	650	[illegible]	3,212	13.08	[illegible]	[illegible]	[illegible]

TABLE III: TOBACCO-WHEAT-CLOVER ROTATION: AVERAGE YIELDS BY PERIODS.

Plot	Tobacco									Wheat		Clover	Plot
	First rotation—1903-5			Second rotation—1906-8			6-year average, 1903-8			5-year average, 1904-8		4-year average	
	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	Grain	Straw	1905-1908	
No.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Bus.	Lbs.	Lbs.	No.
1	500	136	636	497	163	660	498	150	648	12.08	1,694	2,565	1
2	650	187	837	807	208	1,015	728	198	926	18.45	2,560	3,335	2
3	917	160	1,077	1,110	177	1,287	1 013	169	1,182	20.63	2,743	3,910	3
4	450	157	607	493	154	647	471	156	627	11.72	1,622	2,370	4
5	787	130	917	770	167	937	778	149	927	18.46	2,249	3,190	5
6	907	190	1,097	1,092	196	1,288	999	193	1,192	22.89	2,926	4,020	6
7	510	157	667	568	163	732	539	160	699	13.38	1,741	2,495	7
8	983	133	1,117	1,298	177	1,475	1,141	155	1,296	23.42	2,899	4,160	8
9	968	157	1,125	1,190	223	1,413	1,079	190	1,269	23.58	2,749	4,305	9
10	423	140	563	502	168	670	462	154	616	12.70	1,598	2,195	10
11	388	117	505	457	168	625	422	143	565	12 95	1,639	2,750	11
12	857	170	1,027	1,198	160	1,358	1,027	165	1,192	23.98	2,949	3,875	12
13	972	197	1,170	1,337	167	1,503	1,154	182	1,336	27.04	3,178	4,745	13
14	397	127	523	457	138	595	427	132	559	12.04	1,565	2,425	14
15	1,010	150	1,160	1,252	147	1,398	1,131	148	1,279	26.27	3,011	4,055	15
16	963	150	1,113	1,186	163	1,348	1,074	157	1,231	23.83	2,798	3,865	16
17	347	123	470	442	157	598	394	140	534	11.85	1,507	2,515	17
18	647	113	760	995	180	1,175	821	147	968	24.21	2,747	3,995	18
19	773	127	900	1,100	177	1,277	936	152	1,088	24.26	2,778	3,860	19
20	287	120	407	430	158	588	358	139	497	10.43	1,278	2,470	20
21	454	138	592	463	147	610	458	143	601	11.13	1,388	2,465	21
22	850	163	1,013	1,067	210	1,277	958	127	1,145	22.80	2,820	3,615	22
23	870	170	1,040	1,112	187	1,298	991	178	1,169	22.65	2.669	3,780	23
24	440	127	567	508	143	652	474	135	609	10.24	1,229	2 050	24
25	913	153	1,067	1,104	177	1,283	1,010	165	1,175	22.98	2,645	3,435	25
26	904	133	1,037	1,182	188	1,370	1,042	161	1,203	23.51	2,701	3,560	26
27	383	137	520	477	148	625	430	142	572	10.90	1,302	1,865	27
28	873	134	1,007	1,162	177	1,338	1,017	155	1,172	24.18	2,690	3,680	28
29	693	120	813	1,093	177	1,270	893	149	1,042	19.67	2,232	3,710	29
30	320	113	433	458	143	601	389	128	517	11.27	1,336	1,800	30
31	404	116	519	537	133	670	470	125	595	10.53	1,296	1,845	31
32	793	113	907	993	137	1,130	893	125	1,018	21.88	2,691	3,185	32
33	753	133	887	1,218	167	1,385	985	150	1,136	26.27	3,112	3,995	33
34	357	133	490	500	140	640	428	137	565	10.42	1,227	2,055	34
35	747	140	887	1,040	160	1,200	893	150	1,043	23.10	2,662	3,940	35
36	787	113	900	1,003	137	1,140	895	125	1,020	22.72	2,749	3,655	36
37	330	113	443	480	133	613	405	123	528	9.91	1,325	1,875	37
38	750	123	873	925	137	1,062	837	130	967	21.16	2,568	3,035	38
39	803	133	937	773	150	923	788	142	930	19.01	2,287	3 180	39
40	300	117	417	437	142	578	368	129	497	8.98	1,152	1,620	40
*	393	129	522	482	149	631	437	139	576	11.25	1,432	2,211	

* Average unfertilized yield.

The fertilizers and manures are all applied to the tobacco, the wheat and clover following without any treatment.

Comparing the increase on the first five fertilized plots, as given in Table IV, we find that each application of fertilizers has produced a profitable increase of crop, but the gain from the complete fertilizer, as applied on Plot 8, carrying nitrogen, phosphorus and potassium, all three, has been so much greater than that from any partial fertilizer, as to more than offset the greatly increased cost, so that the largest net gain has resulted from this application.

When the potassium in this fertilizer is increased, on Plot 9, the total tobacco yield remains the same, while that of wheat and hay are slightly increased; but while the total tobacco yield is stationary, there appears to have been a small transfer from the valuable parts of the plant to those less valuable and the consequence is a slight reduction in the total value of the output, and of course a greater one in the net value.

On the other hand, the reduction of the potassium, on Plot 12, results in a falling off in yield sufficient to more than neutralize the saving in the cost of the fertilizer, and a still greater loss occurs when it is entirely omitted, on Plot 6.

When sulphate of potash is substituted for the muriate, on Plot 23, there is a reduction in yield, as compared with Plot 8; and as the sulphate is more expensive than the muriate there is a still greater reduction in the net gain.

This comparison of sulphate with muriate of potash is repeated on two limed plots, numbers 25 and 26, and here again the sulphate falls behind the muriate in total yield and net gain, the loss being chiefly in the tobacco, as the wheat shows a small gain.

The substitution of the nitrate of potash, on Plot 22, has been followed by a still greater reduction in yield.

When the phosphorus is increased, on Plot 13, there is a marked gain in yield, this plot producing a greater total yield and a greater net gain than any other one in the series; while the reduction of the phosphorus, on Plot 19, is followed by a reduction in net gain as well as in total yield.

The increase of the nitrogen, on Plot 15, brings up the total yield to the second highest point in the series, and notwithstanding the high cost of nitrogen in nitrate of soda, this plot also gives next to the highest net gain. Comparing Plot 3, which receives phosphorus and potassium, but no nitrogen, with Plots 8 and 15, which receive the same quantities of phosphorus and potassium, in the

same carriers, reinforced with 240 pounds of nitrate of soda on Plot 8 and 360 pounds on Plot 15, it will be seen that the total gain is increased from $56.82 on Plot 3 to $66.62 on Plot 8 and $76.75 on Plot 15.

Comparing nitrate of soda with sulphate of ammonia as carriers of nitrogen, on Plots 8 and 16, and again with lime, on Plots 26 and 28, there is an apparent gain for the sulphate of ammonia in each case.

When nitrogen and phosphorus are given in tankage, on Plots 18 and 29, there is so great a reduction in the yield of tobacco as to much more than offset the small saving in the cost of the fertilizer. As tankage is the carrier of nitrogen usually employed in ready-mixed fertilizers this becomes an important point, the more so as the farmer generally pays more for the pound of nitrogen in such fertilizers than he would need to pay in nitrate of soda.

The manure used in this experiment for the first rotatation was horse manure; since then it has come from cattle, but in both cases it has accumulated on earth floors. Theoretically, ten tons of such manure should contain, when unleached, 75 to 80 pounds each of nitrogen and potassium and 25 to 30 of phosphorus. On this basis the constituents of the manure have not been quite as effective, pound for pound, as the same constituents in the chemical fertilizer. It will be observed, however, that when the manure has been used at the rate of 10 tons per acre it has produced increase to the average value of more than $5.00 per ton of manure.

Comparing Plots 32 and 35 it appears that the reinforcement of the manure with phosphorus (in the form of floats, and at the rate of approximately 40 pounds to the ton of manure) has materially increased its effectiveness. When thus treated there has been no practical difference in the effect of the yard and shed manure, but when both kinds of manure, untreated, have been followed by lime there has been a considerable superiority in the unleached manure.

EFFECT OF LIME.

The effect of lime is shown in Table V, in which are contrasted the yields of 5 pairs of plots, which are treated alike in all respects except the use of lime. Apparently lime is not yet needed on this soil for the crops grown in this experiment, the soil being chiefly derived from decomposition of limestone and limestone gravels.

TABLE IV: TOBACCO-WHEAT-CLOVER ROTATION. AVERAGE INCREASE, COST OF FERTILIZER AND NET GAIN PER ACRE.

Plot	Fertilizing elements per acre			Average increase per acre						Cost of fertilizers	Total value of Increase	Net gain	Plot
				Tobacco, 6-year average			Wheat, 5-yr. average		Clover 4-year Average				
	Phosphorus	Potassium	Nitrogen	Wrapper and filler	Trash	Total	Grain	Straw					
No.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Bus.	Lbs.	Lbs.	$	$	$	No.
2	30	..	..	239	46	285	6.48	890	821	3.90	29.17	25.27	2
3	30	75	..	532	16	548	8.81	1,097	1,470	8.40	56.82	48.42	3
5	..	75	38	284	—7	277	6.20	587	782	11.70	31.29	19.59	5
6	30	..	38	482	35	517	10.06	1,224	1,573	9.10	54.64	45.54	6
8	30	75	38	627	—3	624	10.26	1,205	1,772	15.60	66.62	51.02	8
9	30	125	38	591	34	625	10.65	1,104	2,012	18.60	65.46	46.86	9
12	30	50	38	604	26	630	11.33	1,328	1,233	14.10	64.03	49.93	12
13	45	75	38	731	46	777	14.69	1,574	2,212	17.55	81.34	63.79	13
15	30	75	57	714	14	728	14.46	1,462	1,600	19.20	76.75	57.55	15
16	30	75	38	669	19	688	12.25	1,265	1,400	15.60	70.46	54.86	16
18	30	75	38	438	7	445	13.17	1,316	1,495	13.90	52.97	39.07	18
19	20	75	38	567	12	579	13.52	1,423	1,375	14.30	63.28	48.98	19
22	30	75	38	494	47	541	11.97	1,485	1,288	15.60	56.43	40.83	22
23	30	75	38	522	41	563	12.11	1,406	1,592	16.50	59.83	43.33	23
25	30	75	38	550	28	578	12.52	1,387	1,446	19.50	62.00	42.50	25
26	30	75	38	597	21	618	12.83	1,424	1,633	18.60	66.39	47.79	26
28	30	75	38	601	17	618	13.16	1,377	1,837	18.60	67.58	48.98	28
29	30	75	38	490	16	506	8.52	907	1,888	16.90	54.71	37.81	29
32	..	..	..	437	—3	434	11.39	1,418	1,270	.....	50.52	.....	32
33	..	..	..	543	23	566	15.82	1,862	2,010	.....	66.34	.....	33
35	..	..	..	473	18	491	12.86	1,403	1,945	.....	57.58	.....	35
36	..	..	..	482	—3	479	12.64	1,457	1,720	.....	56.97	.....	36
38	..	..	..	443	5	448	11.56	1,319	1,242	.....	51.04	.....	38
39	..	..	..	409	15	424	9.73	1,079	1,475	.....	47.70	.....	39
Average unfertilized yield...............				437	139	576	11.25	1 432	2 046				

The formula which is thus far producing the greatest increase in this experiment, that used on Plot 13, is made up as follows:

Fertilizing material	Pounds of essential constituents		
	Ammonia Lbs.	Phosphoric acid Lbs.	Potash Lbs.
Nitrate of soda. 240 lbs.	45	....	....
Acid phosphate, 720 lbs.	....	100	....
Muriate of potash, 180 lbs.	....	....	90
Total 1140 lbs.	45	100	90
Percentage	4	9	8

The percentages of "ammonia", "phosphoric acid" and "potash" are given above for the convenience of those who are accustomed to the use of this method of reckoning, but it must not be expected that the ordinary ready-mixed fertilizers will produce results equal to those obtained from these materials, although their cost will usually be greater.

TABLE V: EFFECT OF LIME ON TOBACCO, WHEAT AND CLOVER, GROWN IN ROTATION

Plot	Treatment	Average increase per acre			Value of Increase	
		Tobacco	Wheat	Hay	Total	Net
No.		Lbs.	Bus.	Lbs.	$	$
8	Acid phosphate, muriate potash, nitrate soda......	624	10.26	1,772	66.62	51.02
26	" " " " " lime.	618	12.83	1,633	66.39	47.79
23	Acid phosphate, sulphate potash, nitrate soda......	563	12 11	1,592	59.83	43.33
25	" " " " " " lime..	578	12.52	1,446	62.00	42.50
16	Acid phoshate, muriate potash, sulphate ammonia.	688	12.25	1,400	70.46	54.86
28	" " " " " " lime.	618	13.16	1,837	67.58	48.98
18	Tankage, muriate potash..........................	445	13.17	1,495	52.97	39.07
29	" " " lime.....................	506	8.52	1,888	54.71	37.81
32	Untreated shed manure..............................	434	11.39	1,270	50.52	
38	" " " lime...........................	443	11.56	1 242	51.04	

II. FERTILIZERS AND MANURE ON TOBACCO GROWN CONTINUOUSLY ON THE SAME LAND.

Following is the plan of fertilizing in this test, the quantities being pounds per acre:

Plot	1, None									
"	2, Acid phosphate,	160 lbs;	muriate potash,			60 lbs.;	nitrate soda,			80 lbs.
"	3, "	"	160 "	"	"	60 "	"	"		160 "
"	4, None									
"	5, Acid phosphate,	160 lbs;	muriate potash,			60 lbs.;	nitrate soda,			320 lbs.
"	6, "	"	160 "	"	"	60 "	"	"		480 "
"	7, None									
"	8, Acid phosphate,	320 lbs;	muriate potash,			60 lbs.;	nitrate soda			320 lbs.
"	9, "	"	320 "	"	"	120 "	"	"		320 "
"	10, None									

Plots 11 to 18, inclusive, are cross dressed with untreated shed manure, 8 tons per acre. The following additional treatment is given:

Plot 11, None.
" 12, Acid phosphate, 160 lbs.
" 13, Acid phosphate, 160 lbs.; muriate potash, 60 lbs.; nitrate soda, 160 lbs.
" 14, None.
" 15, Acid phosphate, 160 lbs.; muriate potash, 60 lbs.; nitrate soda, 320 lbs.
" 16, Phosphated shed manure, 5 tons.
" 17, None.
" 18, Phosphated yard manure, 5 tons.

Table VI gives the statistics of this experiment for 1906, 1907, and 1908 (continuing the record from Bulletin 172) with averages by periods, and the results are summarized in Table VII.

The cost of fertilizers, value of increase and net gain are computed annually in Table VII, whereas they are computed for each rotation of 3 years in Table III. In Table VIII the results of similar treatment are compared for the two 3-year periods during which the experiment has been in progress. This table shows that under each similar method of treatment there has not only been a smaller yield in the tobacco grown continuously than in that grown in rotation, which indeed is to be expected, since the rotated tobacco gets larger applications of fertilizer and manure than that grown continously, but that the rotated tobacco has increased in yield during the second period, as compared with the first, whereas that grown continuously has fallen off in yield in every case except on Plot 2, and there the gain has been very small. Reference to Table VI will show that even on the very heavily fertilized and manured plots in the continuous culture there has been a reduction in yield during the second period, as compared with the first.

TABLE VI: STATISTICS OF PRODUCTION OF TOBACCO GROWN CONTINUOUSLY, 1903 TO 1908.

Yield per acre

Plot	1906			1907			1908			3-year average, 1903-5			3-year average, 1906-8			6-year average, 1903-8			Plot
	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	
No.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	No.
1	380	220	600	190	100	290	225	150	375	355	130	485	265	157	422	311	143	453	1
2	850	220	1,070	560	140	700	650	130	780	663	150	813	687	163	850	675	157	832	2
3	980	200	1,180	545	140	685	575	150	725	763	147	910	700	163	863	732	155	887	3
4	420	180	600	235	120	355	210	120	330	317	163	480	288	140	428	302	152	454	4
5	1,030	240	1,270	730	150	880	740	140	880	806	167	973	833	177	1,010	820	172	992	5
6	1,125	220	1,345	745	140	885	680	140	820	763	164	927	850	167	1,017	807	165	972	6
7	280	170	450	165	95	260	145	135	280	303	120	423	197	133	330	250	127	377	7
8	1,160	220	1,380	820	160	980	805	130	935	837	193	1,030	928	170	1,098	882	182	1,064	8
9	1,330	180	1,510	880	150	1,030	875	150	1,025	963	147	1,110	1,028	160	1,188	996	153	1,149	9
10	240	120	360	140	90	230	165	140	305	210	110	320	182	117	299	196	113	309	10
*	330	172	502	182	101	283	186	136	322	296	131	427	233	137	370	265	134	309	
	Cross dressed with untreated manure, 8 tons per acre																		
11	850	130	980	500	140	640	595	125	720	760	280	1,040	648	132	780	738	159	897	11
12	955	170	1,125	725	155	880	760	155	915	720	350	1,070	813	160	973	808	188	996	12
13	1,280	180	1,460	940	180	1,120	850	150	1,000	1,050	260	1,310	945	160	1,105	1,006	172	1,178	13
14	1,070	140	1,210	540	140	680	615	120	735	990	160	1,150	742	133	875	809	137	946	14
15	1,350	140	1,490	1,020	150	1,170	940	110	1,050	1,320	230	1,550	1,103	133	1,236	1,100	152	1,252	15
16	1,400	130	1,530	1,025	150	1,175	1,040	110	1,150	1,230	220	1,450	1,155	130	1,285	1,121	145	1,266	16
17	1,160	200	1,360	830	160	990	865	135	1,000	940	370	1,310	952	165	1,117	909	189	1,098	17
18	1,290	180	1,470	1,160	140	1 300	1,010	135	1,145	1,120	260	1 380	1,153	152	1,305	1,103	161	1,264	18
**	1027	157	1,183	623	147	770	692	127	819	897	270	1 167	781	143	924	819	162	931	
	Increase per acre																		
2	457	13	470	355	33	388	430	—10	420	373	— 63	310	414	12	426	367	11	378	2
3	573	7	580	325	27	352	360	20	380	547	—107	440	419	18	437	427	6	433	3
5	656	64	720	518	38	556	551	15	566	690	— 40	650	575	39	614	536	28	563	5
6	799	47	846	557	37	594	514	10	524	560	.....	560	623	32	655	539	30	569	6
8	893	67	960	664	67	731	663	— 7	656	673	127	800	740	42	782	652	59	711	8
9	1,077	43	1,120	731	58	789	717	12	729	877	— 7	870	842	38	880	782	35	817	9
12	32	37	69	211	15	226	158	32	190	—113	110	—3	134	28	162	42	32	74	12
13	283	43	326	414	40	454	242	28	270	137	60	197	313	37	350	221	28	249	13
15	250	—20	230	383	3	386	242	—15	227	346	.....	346	891	—37	854	257	— 2	255	15
16	270	—50	220	292	— 3	289	258	—20	238	274	— 80	194	820	—73	747	245	—27	218	16
18	130	—20	110	330	—20	310	145	....	145	180	—110	70	202	—13	189	194	—28	166	18

* Average unfertilized yield.

** Average yield of plots receiving manure only, 8 tons per acre.

TABLE VII: TOBACCO GROWN CONTINUOUSLY: SUMMARY OF RESULTS FOR 6 YEARS.

Plot No.	Treatment	Cost of fertilizers	Value of Increase	Net gain
2	Acid phosphate, 160 lbs.; muriate potash, 60 lbs.; nitrate soda, 80 lbs.	$ 5.20	$ 29.52	$ 24.34
3	" " 160 " " " 60 " " " 160 "	7.60	34.45	26.85
5	" " 160 " " " 60 " " " 320 "	12.40	43.22	31.82
6	" " 160 " " " 60 " " " 480 "	17 20	43.57	26.37
8	" " 320 " " " 60 " " " 320 "	13.70	53 05	39.35
9	" " 320 " " " 120 " " " 320 "	15.20	63.08	47.88
11-14-17	8 tons manure.	.....	44.74	.....
12	" " and 160 lbs., acid phosphate.	1.30	46.58	.....
13	" " and same fertilizers as on Plot 2	7.60	62.94	.....
15	" " " " " " " " 3	12.40	65.27	.....
16	" " " 5 tons phosphated shed manure.	1.30	63.94	.....
18	" " " " " yard "	1.30	59.74	.....

TABLE VIII: COMPARISON OF YIELDS OF TOBACCO PER ACRE IN CONTINUOUS AND ROTATIVE CROPPING.

Treatment			First period, 1903-5			Second period, 1906-8		
Fertilizers per acre per period	Cropping	Plot	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total
		No.	Lbs.	Lbs.	Lbs	Lbs.	Lbs.	Lbs.
None	Rotative	a	393	129	522	482	149	631
	Continuous	b	296	131	427	233	137	370
Acid phosphate, 480 lbs.; muriate potash, 180 lbs.; nitrate soda, 240 lbs.	Rotative	8	963	133	1,117	1,298	177	1,475
	Continuous	2	663	150	813	687	163	850
Acid phos., 480 lbs.; mur. potash, 180 lbs.; nit. soda, 360 lbs.	Rotative	15	1,010	150	1,160	1,252	147	1,398
" " 480 " " " 180 " " " 480 "	Continuous	3	763	147	910	700	163	863
Untreated shed manure, 20 tons	Rotative	33	763	133	887	1,218	167	1,385
" " " 24 "	Continuous	c	897	270	1,167	781	143	924

a Average of all unfertilized plots.
b Average of Plots 1, 4, 7 and 10.
c Average of Plots 11, 14 and 17.

III. FERTILIZERS AND MANURE ON CORN AND WHEAT GROWN IN ROTATION WITH CLOVER.

The plan of this cereal rotation is shown in Table IX. The statistics for the first 3 years of the experiment, 1905 to 1906, inclusive , are given in Bulletin 184, and those for 1907 and 1908 follow in Table X, while Table XI is a summary of the results for the entire period of the experiment.

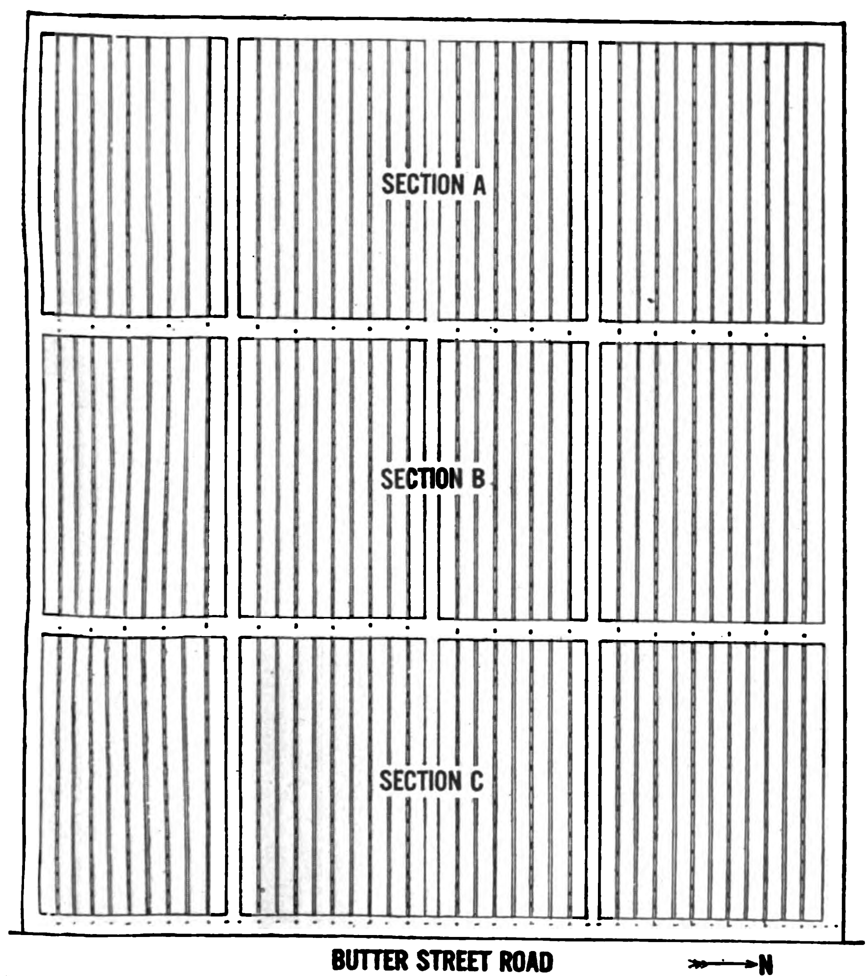
TABLE IX: PLAN OF FERTILIZING IN CORN-WHEAT-CLOVER ROTATION AT THE GERMANTOWN TEST-FARM.

Plot No.	Fertilizing materials—pounds per acre								Fertilizing elements—pounds per acre.		
	On corn			On Wheat				Total fertilizers for one rotation			
	Acid phosphate	Muriate of potash	Nitrate of soda	Acid phosphate	Muriate of potash	Dried Blood	Nitrate of soda		Phosphorus	Potassium	Nitrogen
1	....	....	...	....	....	....	....	....	. ..	....	....
2	120	....	....	120	.. .	....	....	240	15	....	....
3	120	20	....	120	20	....	....	280	15	16½	....
4	....	....	....	....	....	....	....	....	....	....	....
5	....	20	80	....	20	30	60	210	....	16½	25⅓
6	120	....	80	120	....	30	60	410	15	....	25⅓
7	....	....	....	....	....	....	....	...	....	....	....
8	120	20	80	120	20	30	60	450	15	16½	25⅓
9	120	20	160	120	20	30	140	610	15	16½	50⅔
10	....	....	....	....	....	....	....	....	....	....	....
11	120	40	160	120	40	30	140	650	15	33	25⅓
12	240	20	80	240	20	30	60	710	30	16½	25⅓
13	....	....	...	....	....	....	....	....	....	....	....
14	240	40	160	240	40	30	140	890	30	33	50⅔
15	480	80	320	Lime, 1,000 pounds				890	30	33	50⅔
16	....	....	....	....	....	....	....	....	....	....	....
17	Untreated shed manure 5 tons on corn; lime, 1,000 lbs. on wheat.										
18	Untreated shed manure 10 tons, 1904-5-6; lime, 1,000 lbs., 1907-8-9; manure and lime on corn only.										
19	....	....	....	....	....	....	....	....	....	....	....
20	Untreated shed manure 10 tons, 1903-4-5; lime 1,000 lbs., 1906-7-8; manure and lime on wheat only										
21	Lime, 1,000 lbs. on corn; untreated shed manure, 5 tons on wheat.										
22	Unfertilized.										
23	Untreated yard manure, 5 tons, on corn only.										
24	Untreated shed manure, 5 tons, on corn only.										
25	Unfertilized.										
26	Phosphated yard manure, 5 tons on corn only.										
27	Phosphated shed manure, 5 tons on corn only.										
28	Unfertilized.										
29	Phosphated shed manure, 5 tons on corn; lime, 1000 lbs. on wheat.										
30	Tankage, 680 lbs; muriate of potash, 80 lbs; nitrate of soda, 80 lbs. on corn; lime, 1,000 lbs. on wheat.										
31	Unfertilized.										
32	Tankage, 340 lbs; muriate of potash, 40 lbs; nitrate of soda, 40 lbs; on corn; same on wheat.										
33	Tankage, 340 lbs; muriate of potash, 60 lbs; nitrate of soda, 120 lbs. on corn; same on wheat.										
34	Unfertilized.										
35	Tankage, 220 lbs; acid phos., 200 lbs; muriate of potash, 20 lbs. on corn; same on wheat.										
36	Tankage, 220 lbs; acid phos., 200 lbs; muriate of potash, 40 lbs; nitrate of soda, 80 lbs. on corn; same on wheat.										
37	Unfertilized.										
38	Tankage, 500 lbs; muriate of potash, 60 lbs; nitrate of soda, 60 lbs. on corn; same on wheat.										
39	Tankage, 170 lbs; nitrate of soda, 18 lbs. on corn; same on wheat,										
40	Unfertilized.										

Table XI shows that acid phosphate, when used alone at the rate of 120 pounds per acre each on corn and wheat, has produced a profitable increase in each crop, as well as in the clover following, the total value of the increase amounting to more than 4 times the cost of the fertilizer.

When the very small quantity of 20 pounds per acre of muriate of potash is added to this dressing of acid phosphate the total and net gain are largely increased, and that this increase is not due to accidental variations in the soil is indicated by comparing Plot 6, which receives nitrate of soda and acid phosphate, but no potash, with Plot 8, which receives the same quantities of nitrate of soda and acid phosphate, with 20 pounds of muriate of potash in addition. It seems evident, therefore, that both phosphorus and potassium are needed in the fertilizer to produce the best results on this soil.

DIAGRAM III: ARRANGEMENT OF PLOTS IN CORN-WHEAT-CLOVER ROTATION



Plots are numbered from left to right in each section. Dotted lines indicate tile drains.

That nitrogen also is needed is seen by comparing Plot 6, receiving nitrogen and phosphorus, with Plot 2, receiving phosphorus only; or by comparing Plot 8, receiving nitrogen, phosphorus and potassium, with Plot 3, receiving phosphorus and potassium only. It is true that the net gain is not as large on Plot 8 as on Plot 3, owing to the high cost of fertilizer nitrogen; but when we increase the proportion of phosphorus to nitrogen, on Plot 12, we get a larger net gain than on any other combination of fertilizing materials used in the experiment. It is true that a somewhat larger total increase has been secured on Plots 14 and 33, receiving more nitrogen, but the extra cost of the fertilizer has outrun the value of the increase on these plots.

TABLE X: CORN-WHEAT-CLOVER ROTATION:—STATISTICS OF YIELD FOR 1907 AND 1908.

Plot	Corn				Wheat				Clover	
	Grain		Stover		Grain		Straw		Hay	
	1907	1908	1907	1908	1907	1908	1907	1908	1907	1908
No.	Bus.	Bus.	Lbs.	Lbs.	Bus.	Bus.	Lbs.	Lbs.	Lbs.	Lbs.
1	58.14	28.57	3,100	2,400	12.33	9.83	1,330	1,720	2,310	1,470
2	65.71	33.14	3,410	2,580	15.08	14.42	1,625	2,375	2,750	2,290
3	73.43	42.14	3,900	2,990	20.50	15.00	2,210	2,510	3,110	2,480
4	59.71	32.43	3,190	2,410	14.18	12.83	1,529	2,110	2,900	1,550
5	61.29	39.14	3,410	2,710	15.08	12.87	1,625	2,217	2,820	1,620
6	60.29	40.14	3,210	2,900	19.79	15.79	2,133	2,762	3,550	2,300
7	46.86	40.57	2,600	2,750	11.32	10.12	1,221	1,782	3,160	1,390
8	63.57	52.43	3,540	3,080	21.16	15.08	2,280	2,665	3,350	2,430
9	66.86	55.57	3,680	3,280	21.21	15.79	2,287	2,792	3,190	2,350
10	44.57	49.71	2,760	2,950	11.44	10.70	1,234	1,685	3,240	1,290
11	80.71	61.86	4,580	3,620	21.99	17.17	2,371	2,840	3,820	2,520
12	77.71	66.00	4,800	3,780	23.95	17.00	2,583	2,630	3,780	3,860
13	63.86	52.00	3,630	3,240	13.64	10.92	1,472	1,645	3,030	1,390
14	81.86	63.71	5,120	3,800	25.03	18.04	2,698	2,967	3,750	4,100
15	84.00	52.43	5,770	3,850	21.81	14.83	2,351	2,240	3,780	2,630
16	50.43	39.71	3,170	2,550	13.94	9.17	1,504	1,390	2,670	1,670
17	70.71	56.14	4,700	3,720	19.43	12.83	2,094	2,080	3,960	2,760
18	71.57	50.00	4,790	3,300	19.07	11.04	2,056	1,857	3,820	2,330
19	60.86	46.14	3,850	2,920	14.84	10.37	1,600	1,557	3,270	1,630
20	70.29	44.57	4,410	2,750	21.69	10.21	2,339	1,687	3,770	2,990
21	60.29	38.14	3,560	2,550	23.30	12.96	2,512	2,152	3,440	3,090
22	45.71	35.86	2,900	2,460	15.14	7.21	1,632	1,267	3,160	1,760
23	53.43	41.00	3,110	2,420	18.42	8.21	1,985	1,437	3,760	2,060
24	61.71	46.71	3,650	2,720	20.08	10.62	2,165	1,792	4,070	2,140
25	37.57	32.29	2,510	2,280	13.82	6.21	1,491	1,267	3,010	1,800
26	60.43	41.71	3,350	2,700	18.59	13.00	2,005	2,190	3,350	1,920
27	75.00	49.00	4,250	2,660	16.51	13.04	1,779	1,967	3,590	2,130
28	68.57	40.00	3,690	2,530	10.91	7.67	1,175	1,510	3,030	1,520
29	81.00	47.29	5,100	3,100	18.30	15.29	1,972	2,392	3,780	2,460
30	81.71	58.00	5,010	3,450	22.47	12.17	2,422	2,250	4,170	3,390
31	51.71	41.86	3,050	2,610	17.34	7.17	1,869	1,530	3,320	2,490
32	63.14	56.29	3,360	3,360	29.38	14.17	3,167	2,670	4,120	4,750
33	66.86	53.29	4,150	3,290	31.23	15.54	3,366	2,967	4,230	4,800
34	33.43	33.71	2,250	2,520	21.93	5.17	2,364	1,160	2,830	3,700
35	59.29	47.71	3,450	2,790	29.92	14.50	3,225	2,480	3,600	5,600
36	64.43	45.71	3,780	2,690	29.50	15.37	3,180	2,657	3,590	5,470
37	48.43	26.86	2,900	2,560	21.21	4.58	2,287	825	2,090	3,850
38	66.14	44.57	4,330	2,960	26.46	11.83	2,852	1,890	3,800	5,270
39	60.43	27.43	3,600	1,950	18.95	6.75	2,043	1,155	2,350	3,610
40	59.71	25.29	4,100	1,830	14.06	4.42	1,580	835	1,880	2,050
*	52.11	87.50	3 121	2 501	14.84	8.31	1 592	1 449	2 850	1 969

*Average unfertilized yield.

TABLE XI: CORN-WHEAT-CLOVER ROTATION: AVERAGE INCREASE, COST OF FERTILIZERS AND NET GAIN PER ACRE, 1905 to 1908.

Plot	Fertilizing elements per acre			Average increase per acre					Cost of ferti-lizers	Value of increase	Net Gain	Plot
	Phos-phorus	Potas-sium	Nitro-gen	Corn: 5-year av.		Wheat: 4-year av.		Clover 4-yr. av.				
				Grain	Stover	Grain	Straw.					
No.	Lbs.	Lbs.	Lbs.	Bus.	Lbs.	Bus.	Lbs.	Lbs.	$	$	$	No.
2	15	....	....	7.28	213	4.54	447	453	1.90	9.12	7.22	2
3	15	16½	...	11.31	494	5.90	614	657	2.90	13.23	10.33	3
5	..	16½	25⅓	4.43	247	1.27	166	244	5.80	4.30	—1.50	5
6	15	....	25⅓	7.76	313	6.89	724	711	6.70	12.65	5.95	6
8	15	16½	25⅓	12.21	479	7.65	849	736	7.70	15.51	7.81	8
9	15	16½	50⅔	10.99	373	7.89	944	556	12.50	14.43	1.93	9
11	15	33	25⅓	16.21	872	9.71	1,137	942	13.50	20.46	6.96	11
12	30	16½	25⅓	15.99	850	10.43	1,165	1,328	9.60	22.49	12.89	12
14	30	33	50⅔	17.37	862	12.61	1,464	1,090	15.40	24.15	8.75	14
15	30	33	50⅔	18.34	1,336	6.52	736	707	17.90	18.18	.28	15
17	..	....	....	16.91	1,013	4.28	500	744	.....	15.18	......	17
18	..	....	....	13.13	905	5.03	576	566	.....	13.47	......	18
20	..	....	....	13.03	621	5.07	552	1,027	.....	14.86	......	20
21	..	....	....	2.05	—14	3.34	414	823	.....	7.18	......	21
23	..	....	....	12.78	413	1.67	163	286	.....	8.37	......	23
24	..	....	....	19.16	701	5.15	535	461	.....	15.21	......	24
26	..	....	....	11.66	395	4.07	462	145	.....	9.55	......	26
27	..	....	...	13.23	525	3.52	330	189	.....	9.98	......	27
29	..	....	....	13.67	944	5.11	570	484	.....	13.48	......	29
30	30	33	50⅔	15.88	1,043	6.35	658	779	17.90	16.77	1.13	30
32	30	33	50⅔	14.33	601	9.92	1,087	1,144	15.40	20.23	4.83	32
33	30	50	76	15.76	916	11.47	1,294	1,118	21.20	22.62	1.42	33
35	44	16½	25⅓	13.77	579	8.96	1,017	1,161	11.50	19.20	7.70	35
36	44	33	50⅔	13.60	599	11.03	1,263	1,069	17.30	20.68	3.38	36
38	44	50	76	14.15	799	10.15	1,093	1,116	22.10	20.53	—1.57	38
39	15	....	25⅓	3.38	—33	2.34	248	283	6.70	4.55	2.15	39
Average unfertilized yield..................				45.84	2,648	10.7	1,316					

Plot 12 receives 160 pounds of nitrate of soda, carrying about 25 1-3 pounds of nitrogen, equivalent to 30 pounds of "ammonia;"* 480 pounds of 14 percent acid phosphate, carrying 30 pounds of phosphorus or 68 pounds of "phosphoric acid," and 40 pounds of muriate of potash, carrying 16 1-2 pounds of potassium or 20 pounds of "potash."

As fertilizers are ordinarily computed the percentage composition of this mixture would be approximately as below:

Carrier	Pounds of essential constituents: Ammonia	Phosphoric Acid	Potash
160 lbs. nitrate of soda	30	...	...
480 lbs. acid phosphate	...	68	...
40 lbs. muriate of potash	...	...	20
680 lbs. total	30	68	20
Percentage	4	10	3

Five tons of fresh manure, as used on Plot 24, should contain approximately the same quantities of nitrogen and phosphorus and about twice as much potassium as have been used on Plot 9. Comparing Plots 24 and 9 we see that the corn has made a larger increase on Plot 24 and the wheat and clover on Plot 9, the total value of the increase being slightly greater on Plot 24. Had Plot 24 received the same chemical fertilizers as Plot 9, but all in one application to the corn crop, the result would undoubtedly have been a larger increase in that crop and a smaller one in the wheat and clover, with probably a smaller total increase on all the crops (compare Plots 14 and 15, Table XI.) Hence it is fair to conclude that the chemical constituents of the fresh manure are producing practically the same effect as those in the chemicals. The results attained on the manured plots as a whole, however, are as yet inconclusive. The shed manure has been followed by a greater average increase than the yard manure, but the untreated manure has apparently produced a larger increase than that reenforced with floats, whether we compare Plot 17 with 29 or Plots 23 and 24 with 26 and 27. A careful analysis of the results, however, indicates that this outcome is largely due to inequalities in soil conditions which will probably be eliminated, in part at least, as the work progresses. It will be remembered that in these experiments there are as many separate tracts or sections of land as there

*Ammonia is a compound of nitrogen with hydrogen, containing about 82 percent nitrogen; phosphoric acid is a compound of phosphorus with oxygen, containing about 44 percent phosphorus, and potash is a compound of potassium with oxygen, containing nearly 84 percent potassium.

are crops in the rotation. In the one under consideration the corn crop, grown on Section A in 1904, yielded 30.14 bushels per acre for the untreated manure and 32.28 bushels for the phosphated manure. In 1907 the yields on the same land were 57.57 and 68.57 bushels, respectively, for the treated and untreated manure. In 1905 the yields on Section B were 72.00 for untreated and 62.78 for phosphated manure; but in 1908 the yields were 43.85 and 45.35 bushels, respectively, a reversal in both cases of more than 10 bushels per acre in the respective yields. Wheat was grown on Section A in 1905, and the yields, like those of the previous corn crop, were practically the same for the two kinds of manure; but in 1908 the yield for the phosphated manure was nearly 40 percent greater than for that not so treated.

These points illustrate the importance of long continued work on a systematic plan in dealing with such problems as this. On the one hand we have a soil which has been under cultivation for nearly a century and which has probably been subjected to differences in treatment of which we can have no knowledge, and on the other we have a fertilizing substance (floats) notoriously inert and slow in action.

This comparison is being duplicated in the tobacco rotation on the same farm, and here the results are consistent with those attained in the larger test at the main station, where the advantage of reenforcing farm manures with phosphorus is being strikingly demonstrated,* although in this test also the differences shown at the beginning of the work were much smaller than they have grown to be as the work has progressed.

On plots 30 to 39, inclusive, a part or all of the nitrogen and phosphorus is given in tankage, instead of nitrate of soda and acid phosphate. Comparing these with the plots receiving all their nitrogen and phosphorus in nitrate of soda and acid phosphate, it will be seen that tankage has not proved to be as effective a carrier as the other materials. This is a matter of considerable importance to the farmer, since the nitrogen in the ordinary, ready-mixed commercial fertilizer is derived chiefly from tankage.† In computing the cost of the fertilizer the tankage nitrogen is computed at the same price as that in nitrate of soda. In point of fact, the farmer usually pays more for the nitrogen carried in ready-mixed fertilizers than he would need to pay for it in nitrate of soda.

*See Circular 92. p. 25.

†The nitrogen in tankage is in organic form, and must be first converted into ammonia and then into nitric acid before it becomes available. The nitrogen of fresh manure is largely in the form of ammonia, hence it is well on the way towards availability.

It is interesting now to compare the outcome of the first 5 years' work at Germantown with that in the similar experiment at the main station at Wooster for the three 5-year periods over which it has been conducted, as summarized on page 16 of Circular 92. As the experiment at Wooster is a 5-year rotation and that at Germanton is one of 3 years it will be necessary to make the comparison on the basis of the annual value of increase and cost of fertilizer.

TABLE XII. COMPARISON OF RESULTS AT GERMANTOWN AND WOOSTER.

Fertilizing elements	Germantown			Wooster				
	Plot No.	Annual cost of fertilizer	Annual value of increase	Plot No.	Annual cost of fertilizer	Annual value of incre[ase]		
						First 5 years	Second 5 years	Th[ird] 5 ye[ars]
Phosphorus alone	2	$ 0.63	$ 3.04	2	$ 0.52	$1.70	$ 3.47	$4
Phosphorus and potassium	3	0.97	4.41	8	1.82	2.88	4.87	6.
Phosphorus, potassium and nitrogen	8	2.57	5.17	11	4.70	5.28	8.49	9.
" " " "	12	3.20	7.50	17	3.87	3.15	7.32	9.

Table XII shows that the results attained thus far at Germantown, in proportion to quantity of fertilizers, are considerably greater than those reached during the first 5-year period at Wooster. Whether there will be the cumulative effect at Germantown that has been experienced at Wooster remains for the future to determine.

GENERAL CONSIDERATIONS.

The course of agriculture in the Miami Valley has been one of systematic soil exhaustion. Grain crops, timothy and tobacco have been grown continuously or with only occasional short turns in clover; the corn has been sold to the elevators or to the distillers or fed to hogs; the wheat has gone into the general market and the timothy has been sent to the cities. But little manure has been made and that little has largely been wasted. Some restitution has been made to the soil in places by overflow, but more often the overflows have carried away more fertility than they have left. The outcome of this system is that the yield of corn, which during the 20 years, 1850-69, averaged 37.5 bushels per acre for the 5 counties, Montgomery, Preble, Butler, Warren and Hamilton, fell to 34.7 for the 20 years, 1880-99. During the same two periods the yield of wheat was 13.6 bushels for the first period and 14.1 bushels for the second, an increase of half a bushel per acre

Taking the 13 counties comprised in the two tiers lying north of those named, the yields for these two periods have been for corn, 30.1 bushels and 34.6 bushels, and for wheat, 11.7 bushels and 14.4 bushels, a gain of 4.5 bushels of corn and 2.7 bushels of wheat. These counties are now equalling the yields of the Miami Valley in corn and are exceeding their yields in wheat, and the richest region of the state has shifted from this fertile valley to the northwestern counties.

In the ripening of the grain crops about three-fourths of the total phosphorus of the plant is carried into the grain, while about three-fourths of the potassium remains in the straw. Consequently in all regions where grain is largely produced and sold off the farm ordinary soils soon show a deficiency of phosphorus, while in those regions in which not only the grain, but also the straw and hay are removed, both phosphorus and potassium are likely to be exhausted, and this condition applies to the lower Miami Valley; the paper mills and the tobacco warehouses, together with the urgent city demand for hay, having stripped the land of everything that could be carried away except the corn stalks, and that they were not also taken was only due to the fortunate circumstance that they were not adapted to paper making.

Under such conditions it is to be expected that potassium will occupy a position of larger relative importance in the fertilizer than for a region in which the system of agriculture has involved the deportation of grain and animal products chiefly, the straw and hay being retained on the land, and that it will be necessary to restore this element, as well as nitrogen and phosphorus, before maximum yields can be attained.

CONCLUSIONS.

These experiments must be carried much further before final conclusions can safely be drawn, but they have already demonstrated that the yield of crops may be greatly and profitably increased, on the upland soils of the Miami Valley, by the judicious use of manure or chemical fertilizers.

They show that the most effective manure is that which has not been subjected to the losses which occur in the open barnyard, and they indicate that the most effective fertilizer is one containing nitrogen, phosphorus and potassium, all three.

No urgent need of lime has as yet been developed in the soil under these experiments, and this was to be expected from its geological history. It has not yet been demonstrated, however, that moderate applications of lime may not be useful, especially upon those fields in this region which have been longest under cultivation.

THE BALANCE BETWEEN INORGANIC ACIDS AND BASES IN ANIMAL NUTRITION

OHIO

Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., AUGUST, 1909.

BULLETIN 207

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CONTENTS.

PREFACE.

In this bulletin we seek to show the bearing, upon practical animal nutrition, of the relationship between those mineral elements of our foodstuffs and of living animal tissues, which in the body give rise to inorganic acids, and the various means at the disposal of the animal for accomplishing protection from these acids through effecting their neutralization.

The formation of inorganic acids from the food and from the tissues in the animal body, and the necessity for their neutralization, are always present, and therefore students of the effects of foodstuffs upon growth and other proteid increase in animals, must consider this factor in determining the causes of the results produced.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 207. AUGUST, 1909.

THE BALANCE BETWEEN INORGANIC ACIDS AND BASES IN ANIMAL NUTRITION.

BY E. B. FORBES.

INTRODUCTION.

The vital reactions taking place in the bodies of animals require that certain necessary conditions be maintained with unvarying constancy.

None of these conditions is of wider or deeper significance to these vital processes than the state of the liquids and tissues as regards acidity and alkalinity.

Nearly all of the mineral elements in the body contribute to one or the other side of this account and thus become involved in a great number of most important functions.

This balance between acid and alkaline mineral elements in animal bodies is constantly maintained in adjustment by a most intricate system of compensating agencies, so that, under normal conditions, the matter is perfectly accomplished without our conscious intervention.

But we do not always live under "normal" conditions. We have set up standards for both man and his animals which differ greatly from those to which they have been adapted, and we use as foods and feeding stuffs a great variety of artificial products with which it is possible to tax the adaptability of the animal quite beyond the limits of toleration.

Indeed we are each year becoming more and more independent of the environment to which, through long ages of selection, our physiological processes have come to be attuned.

This fact imposes upon us the obligation to seek an understanding of the physiology of nutrition in order that our increasing abilities to shape our own lives may not find us wanting in intelligence to use our capacities to the best possible advantage.

The practical bearing of this subject has to do with normal growth, especially of the bones of animals, and the prevention of malnutrition of the bones—a very common trouble in certain regions; with rickets and osteomalacia in both man and other animals; with osteoporosis in live stock; with "bran disease" or "miller's horse rickets" and with the quality of the bones in horses; with acidosis in infants—a very common and troublesome nutritional disturbance and with diabetes and fevers.

It has a direct bearing on the production of all proteid increase in animals and hence upon the profitability of stock-farming, but especially on the rearing of those animals which are fed most largely upon cereals, especially corn alone, namely, swine and poultry. It has also a less important though an interesting bearing on the feeding of carnivorous animals in captivity, since they do not thrive on a diet of meat alone.

PHYSIOLOGICAL BASIS.

The main facts in physiology regarding the acid and alkaline mineral elements are as follows:

There are in all foodstuffs and in the living tissues of animals, mineral elements in organic combination, which upon oxidation in the body, yield inorganic acids. The animal must be protected from these acids, which would produce profound disturbance of function if allowed to circulate throughout the body. To this end they are neutralized with substances possessing a basic reaction and then, in their neutral condition, are either excreted or used as nutrients.

In this connection we consider especially the acid-reacting elements, sulphur, phosphorus and chlorine and the alkali-reacting elements, sodium, potassium, calcium and magnesium. Iron is not considered, since it is either base or acid according to circumstances and enters into vital activities only in its organic combinations.

THE ACID MINERAL ELEMENTS.

Sulphur enters the body almost wholly in organic combination as a constituent of food-proteins. As these proteins are oxidized in the body most of the sulphur is burned to sulphuric acid and is excreted in the urine as inorganic sulphates.

According to Sherman[1] 80 to 85 percent of the urinary sulphur in the human being is in the form, mostly of inorganic, but partly of ethereal sulphates, the remaining 15 to 20 percent being found in less completely oxidized forms This latter portion is designated "neutral sulphur" and consists of derivatives of taurin from the bile, sulphocyanids from the saliva and a considerable number of other compounds, some known and others as yet not identified.

According to Neuberg and Grosser[2], in addition to the inorganic and ethereal sulphates and the neutral organic compounds of sulphur in the urine, there is also a basic fraction made up of salts of an organic sulphonium base.

In the body, sulphur is used as a constituent of all proteid increase and in the repair of proteid waste. A considerable part of the food-protein, however, is oxidized for the production of energy and its sulphur and phosphorus appear mostly as sulphates and phosphates, in the excreta. The constant waste which there is in the proteids of the living tissues, also contributes to the production of the sulphates and phosphates of the excreta.

Phosphorus enters the body in a great variety of conditions; as inorganic phosphates; as salts of various organic acids; as lecithins, that is, compounds of fat, phosphoric acid and a nitrogenous group; as phosphoproteins and as nucleoproteins.

The distribution of the phosphorus of the excretions between urine and feces is governed by the nature of the food.

In herbivora nearly all of the phosphorus is excreted in the feces. In carnivora almost all of the phosphorus is excreted in the urine; while in omnivora, man included, the distribution of the phosphorus between urine and feces, seems to depend largely on the calcium and magnesium contents of the ration. In man about two-thirds of the phosphorus usually leaves the body in the urine and about one-third in the feces, while an increase of the vegetables in the dietary and of the magnesium and calcium intake, will increase the proportion of the phosphorus leaving the body in combination with mineral bases, in the feces.

In the body, phosphorus serves a multiplicity of purposes, both structural and regulative, and is used both in organic and inorganic combinations.

The urinary phosphorus is chiefly in the form of di- and monohydrogen phosphates of sodium and potassium; less abundantly in the form of phosphates of calcium and magnesium. The phosphorus of the feces is also largely in the shape of phosphates. Phosphorus in various organic combinations also occurs in the feces, including nucleins and ether-soluble compounds.

Chlorine enters the body as chlorides and leaves it almost wholly in the urine, as chlorides. In the body it is used as chlorides and as hydrochloric acid in the gastric juice, principally for regulative and digestive purposes.

THE BASIC MINERAL ELEMENTS.

The mineral bases, calcium, magnesium, sodium and potassium, enter the body mostly as salts of various organic and inorganic acids; though calcium, at least in milk, egg-yolk and seeds, occurs also in organic combination with proteins.

These alkali-reacting elements are used in the body mostly in inorganic combination with phosphoric, sulphuric, hydrochloric and carbonic acids, principally for structural, regulative and catalytic purposes. They leave the body as inorganic salts in combination with the above-mentioned mineral acids.

Thus it is seen that these mineral elements, both acid and basic, enter the body in a great diversity of forms, both organic and inorganic, perform in the body a multiplicity of complicated functions and then leave the body mostly in an inorganic condition.

ACIDOSIS.

Causes. When oxidizable organic compounds, either nitrogenous or acid, containing sulphur or phosphorus, are disintegrated, or when chlorides are decomposed in the animal body, there are formed, from the sulphur, phosphorus and chlorine, the corresponding non-oxidizable inorganic acids. Since these acids cannot be broken up by oxidation and excreted by the lungs, they possess a different significance from oxidizable organic acids. An excess of these or other mineral acids, or of non-oxidizable organic acids, in the body, gives rise to a pathological condition known as acid intoxication or acidosis. Acidosis is a name first used by Naunyn[16] to designate the excess of oxybutyric acid present in the blood in *diabetes mellitus.* It is, however, used to designate intoxication from other acids, either produced within the organism or introduced from without. In the use of this term the idea to be conveyed is that of an *excess* of acid. This may be brought about by the introduction or formation of abnormal amounts of acid, the bases not increasing in the same ratio, in which case the acidosis is said to be "absolute" (Naunyn), or it may be caused by a withdrawal from the body, of alkalis, the acids predominating merely because of this withdrawal of alkali, which type of acidosis was designated as "relative acidosis" by Steinitz.

The existence of acidosis is to be inferred from the excretion, by the kidneys, of an increased proportion of the nitrogen of the urine in the condition of ammonium salts, since ammonia is largely used by the animal to neutralize non-oxidizable acids.

In human pathology acidosis of the first type is most commonly caused by oxybutyric acid. In certain liver diseases lactic acid is also present in considerable quantities and uric, oxalic and aromatic acids may also contribute to its causation.

Diabetic coma or stupor is the result of acidosis, caused by a flooding of the tissues with oxybutyric acid and the related acetic acid. These acids are represented in the urine of healthy human beings by acetone, which may be formed from acetic acid by the splitting off of carbon dioxide.

Stadelman[3] first proved that diabetic coma was caused by an increased formation of these acids and that they were excreted by the kidneys in combination with ammonia.

These acids are formed in the body from fats (Magnus-Levy[17]) and their formation is caused by lack of carbohydrate (Hirschfeld[18]) in the diet, or by derangement of the carbohydrate metabolism, as in diabetes.

Oxalic acid, which is difficultly oxidizable, may also contribute to the causation of acidosis in human beings. It is introduced into the body in foods of vegetable origin and is to some extent formed in the body itself.

Acidosis of the second, or relative type, is caused principally by the sulphuric and phosphoric acids normally produced in the body by the cleavage and oxidation of proteids, either of foods or tissues, containing sulphur and phosphorus as constituent parts.

The formation, from fatty acids and alkalis in the intestine, of soaps, which because either of difficult solubility or of digestive disturbance are passed off in the feces instead of being resorbed, is a prominent factor in the production of the second type, or relative acidosis, particularly in infants suffering from digestive disorders.

The essential cause of acidosis is a disturbance by acids, of the reaction of the blood. Henderson[4] regards both blood and protoplasm to be characterized by "a very faint preponderance of alkalinity."

Neutrality of blood. The cause of this approximate neutrality is, according to Henderson, largely the result of a physico-chemical equilibrium between the carbonic acid, sodium bicarbonate, mono-sodium phosphate and di-sodium phosphate contained therein and maintained by secretory capacity of the lungs and kidneys.

Henderson explains the existence of this equilibrium as follows:

"In protoplasm phosphates are present in very great amount, undoubtedly as mixtures of mono- and di-potassium phosphates and similar salts; such mixtures constitute a nearly neutral solution which has the remarkable property of being able to take up large

quantities of acid or alkali without becoming acid or alkaline. This behavior is easily explained by the facts that acid sufficient to convert all the di-potassium phosphate of such a mixture into mono-potassium phosphate must be added before the slight acidity of mono-potassium phosphate is obtained, and that enough alkali to convert all the acid potassium phosphate into di-potassium phosphate must be added before the faint alkaline reaction of the latter substance is obtained, while, in accordance with the requirements of the concentration law, all mixtures of the two substances are much more nearly neutral than either alone."

Symptoms of acidosis. The symptoms of acute acidosis are "air hunger," rapidity of the pulse, depression, stupor and deep coma. These symptoms seem to result from diminished oxidation, due to an accumulation of carbon dioxide in the tissues. This is caused by the diminished alkalinity of the blood, which results in its inability to transport carbon dioxide to the lungs.

The most important effects of a deficiency of mineral bases or an excess of mineral acids in the body are not made apparent by the above-mentioned acute symptoms. Of vastly greater importance must be the less noticeable influence of slightly unbalanced rations upon the development and general health of animals, when these influences remain operative during long periods of time. Little that is definite is as yet known regarding these effects. We feel safe in assuming, however, since acute malnutrition of the bones may be so readily caused in a few weeks by irrational nutrition, that a slight departure from the optimum relationship of bases to acids in the food, if persisted in during the whole of the growing period, can not be without serious consequences in the development of the skeleton.

Indeed, it is a matter of common knowledge that prevailing methods of feeding of swine in the Corn Belt result in just such a gradual moulding of the style of growth as the animal develops, and this at least partially on account of the acid ash of corn.

After so much has been said about excess of mineral acid in the animal body, a fair question would be: "What about mineral bases? Would not an excess of alkali be equally dangerous?" So it might be, but the body has apparently an entirely adequate method of disposition of alkalis so that injurious excess does not occur. Volatile alkali (ammonia) is excreted in salts of mineral or organic acids, or as urea and fixed alkali (sodium and potassium) and alkaline earths (calcium and magnesium), as salts either of acids such as sulphuric, phosphoric, hydrochloric or carbonic acid, or of certain organic acids.

The neutralization of acids. A very slight disturbance by acids of the reaction of the blood must result in a complete disappearance from it of carbon dioxide. Thus it becomes a matter of much importance to the animal that the neutrality or slight alkalinity of the blood be abundantly safeguarded.

In herbivora this is accomplished by the formation of carbonates, in the body, by oxidation of the abundant organic-acid-salts of sodium, potassium, calcium and magnesium which are found in vegetable foods, and under ordinary circumstances the carbonates thus formed are quite sufficient to meet the requirements of the animal. In this class of animals there is but very slight provision for any other method of neutralization of acids.

Because of the practical inability of herbivora to neutralize acids with ammonia and the limited capacity of carnivora and omnivora to do the same, there comes a time, with increased consumption or production of non-oxidizable acids, and much more quickly with herbivora than with omnivora and carnivora, when the animal is no longer able to maintain the neutrality of its blood and tissues. At this point acute symptoms of acid intoxication, or acidosis, as it is called, appear and death may follow quickly with symptoms of asphyxia.

Omnivora and carnivora consume comparatively little mineral base in combination with organic acid and also comparatively little preformed carbonates. Further than this, their food, being much richer in protein than the food of the herbivora, produces correspondingly greater amounts of sulphuric and phosphoric acids by its cleavage and oxidation within the body. Hence we see that there is necessity for the provision of an extensive acid-neutralizing function in these animals. In accord with this requirement we find that carnivora and omnivora have the capacity to neutralize a certain amount of acid in the body with ammonia. This use of ammonia for acid-neutralization does not increase in extent proportionately with increase in the consumption of protein, however; otherwise there would be no such thing as acidosis from an exclusive protein diet, the fact of the existence of which is abundantly demonstrated.

This ammonia which is used for acid-neutralization has its origin in three distinct processes.

(1) Ammonia is produced in the digestive tract in considerable quantities, and by way of the portal vein and other channels reaches the other tissues of the body. It is also formed in all the organs of the body and by them is contributed, possibly as the carbamate, to the blood. According to Magnus-Levy[5] the process of splitting off ammonia from protein is widely prevalent and generally, or often,

precedes the oxidation of the carbon-containing residue. Thus we may consider ammonia as a normal product of the disintegration of protein and its universal presence in the tissues as affording a slight store of alkali available for acid-neutralization.

(2) A second fraction may be considered to be split off from proteids especially for the purpose of acid-neutralization. Thus Folin[6] says: "In the study of ammonia as a product of metabolism,* it must be remembered that this substance is a base, and its formation in the animal organism is therefore probably quantitatively determined by the necessity of forming salts." Magnus-Levy[7] with the same idea in mind says: "As soon as the amount of acid produced exceeds the amount necessary to neutralize the stored-up ammonia or other alkali, autolysis† sets in, and nitrogenous equilibrium ceases to be maintained."

"In well nourished animals there is always an excess of ammonia present which gradually disappears as the animal is deprived of food. A certain stage will then be reached when the production of acid exceeds the amount of ammonia available for neutralization; the autolytic enzyme them comes into play, liberates amino-acids, etc., which in their turn pass to the alimentary tract, and by means of the metabolic processes taking place then liberate ammonia, which again inhibits the production of nitrogenous degradation products." This second fraction then, may be considered to represent a purposive adjustment.

(3) The third source of ammonia available for acid-neutralization is of much greater importance, quantitatively, than the two above-mentioned. This fraction becomes available through its withdrawal from urea formation in the liver.

In mammals, very much the greater part, about 80 percent, of the nitrogen leaving the body, reaches the kidneys as urea. It is formed chiefly in the liver, though also to slight extent in other organs, and chiefly by synthesis, or constructive reaction, from ammonium compounds, possibly from the carbamate or the carbonate, though probably also formed to some extent (Drechsel[9]) directly from certain proteids by a simple splitting or cleavage of the compound, with the taking up of water, and thus without synthesis or constructive change.

* Metabolism is chemical change due to the processes of life.

† Autolysis is that type of chemical change from complex to simpler compounds which is exemplified in the ripening of beef and cheese. Such changes are produced through the agency of a group of chemical compounds which are universally present in plant and animal tissues and which are known as enzymes.

This formation of urea in the liver, from ammonium compounds, may be spoken of as for the purpose of affording the body protection from ammonia. Thus we may consider that the ammonia in the body, available for purposes of acid-neutralization, comes (1) from the tissues, (2) from body proteids and (3) by withdrawal from urea formation.

The nitrogen of the urine may be caused to appear therein almost wholly as ammonium salts by the administration of mineral acids. Conversely the nitrogen of the urine may, by the administration of alkali carbonates, be caused to appear in the form of urea, with a great reduction in the amount of ammonium salts present.

Walther[10] first proved, with dogs, that after administering hydrochloric acid, there was a marked increase in the ammonium salts of the urine, about three-fourths of the hydrochloric acid being excreted in this form.

Organic acids, in general, cause no increase in the excretion of nitrogen as ammonium salts since they are, as a rule, oxidized to carbon dioxide and water and are excreted in these compounds; benzoic and certain related acids, however, are not oxidized, and oxybutyric, acetic and lactic acids may be, like the mineral acids, excreted in combination with ammonia.

Now, have we right to consider that neutralization of acids by ammonia affords the animal as complete protection as their neutralization by fixed alkalis or alkaline earths?

Voegtlin and King[11] suggest that the ammonium salts themselves may play "an important role in producing the symptoms of these diseases." Intravenous injections of ammonium salts of lactic, hydrochloric and beta-oxybutyric acids produced symptoms of acid intoxication, while intravenous injections of calcium salts completely antagonized the toxic action of the ammonium salts.

According to A. P. Mathews[50] ammonium salts in solution decompose, not only into the ammonium and acid groups but also, to a certain extent, with the taking up of water, into ammonium hydroxide and the free acid. These decompositions may subject the animal to the action of ammonia, as stated by Mathews, and of the acid involved, as implied by Voegtlin and King. Thus we may consider it at least a possibility that neutralization of acids by ammonia does not afford an animal complete protection from these acids.

A second source of acid-neutralizing material in all animals is the calcium salts of the bones and other tissues. Where a ration characterized by a deficiency of mineral bases is fed during a considerable period of time, as for instance, in feeding corn to swine,

(see experiments by the author[12]), the withdrawal of mineral matter from the bones and the prevention of its deposit within them, may affect not only the size and strength of the bones, but the size and general style of development of the animal.

That the calcium of the blood may also be used for acid-neutralization is indicated by the fact of the great variability of the content of blood in this element. According to Albu and Neuberg[18], Bunge found .04 percent of calcium, reckoned as the oxide, while Demstedt and Rumpf found values up to .27 percent. That the calcium content of the blood depends upon the food was proven by Hirschler and Terray who found it varying between .0023-.0051 percent (CaO) in accordance with the food.

Rey[19] also has demonstrated with dogs a very considerable retention of calcium in the blood for some days and Weiske in his experiments with rabbits has, by feeding calcium carbonate with oats, shown an apparent increase in the calcium carbonate in the ash of the bones from 5.5 and 6.2 percent to 7.6 and 8.4 percent.

According to Albu and Neuberg[15], Rüdel found with dogs, after the administration of hydrochloric acid, an increase to twice the quantity, and Gäthjens, after the administration of sulphuric acid, three times the quantity of calcium in the urine; and Caspari, after giving oxalic acid, as much as ten times the normal average. Rumpf saw an increase of 50 percent in the calcium excretion in men, after the administration of lactic acid and sodium lactate.

O. Wellmann[20] found that the calcium and phosphorus excreted from the body during fasting comes from bone substance and S. W. Patterson[21], in experiments with rabbits fed on oatmeal and corn-meal, that the deficiency of these foods in calcium results in a loss of calcium from the bones.

Thus in considering this matter of balance between mineral acid and mineral base in animal nutrition, we must think of the acids as produced (1) by the destruction or katabolism of the body proteids, (2) by the oxidation of food proteids, and (3) to a slight extent by the decomposition of sodium chloride in the formation of gastric juice.

On the other hand we must consider the bases available for their neutralization as contributed principally (1) by the carbonates formed from alkali salts of organic acids in the food, (2) by the withdrawal of ammonia from the formation of urea in the liver, (3) by ammonia split off from body proteids, for the purpose of acid-neutralization, (4) by carbonates and ammonia of the tissues and (5) by the decomposition of sodium chloride in the formation of gastric juice.

Effects of acidosis. The first substantial progress toward an understanding of acidosis was due to the studies of Forster, Bunge and Lunin.

Forster[22] fed dogs and pigeons on practically ash-free food. They succumbed in a very few days. He considered the lack of mineral matter to be the cause of death.

Bunge[23] however, suggested that the fatal termination of the experiment might be due to sulphuric acid produced by the oxidation of protein.

Lunin[24] put this idea to a test by feeding mice on an ash-free diet, with and without sodium carbonate. With the sodium carbonate the mice lived twice as long as without it, because this salt neutralized the acids produced by the oxidation of proteids.

Kemmerich[25] found it impossible to maintain young dogs on meat-scrap from which the minerals had been extracted.

Salkowski[26] and Walter[27] found that the administration of hydrochloric acid to rabbits and dogs resulted in a withdrawal from their bodies of the fixed alkalis, and in death.

Salkowski first learned that acids produced in destructive or katabolic processes of human beings, of carnivora and of herbivora may be excreted united with mineral bases.

Effects of diet of meat. Chalmers Watson[28] has found that in animals fed on an exclusive meat diet the bones present an appearance of delayed and imperfect ossification with increased vascularity, or blood content, and an increase in the number of red blood-corpuscles. The symptoms are very similar to those in rickets in human beings, but microscopic examination shows that they are not identical.

D. Forysth[29] however, fed domestic fowls for periods varying from 11 months to 2 years upon meat, supplemented by lime. The animals remained healthy and their bones normal.

E. J. Spriggs[30] found that rats when fed on meat alone had rough and abnormal coats, but that when lime was added to the diet the appearance of the coat was nearly normal.

Effects of diet of cereals. Weiske[31] found that exclusive oat feeding to young rabbits resulted in a very marked demineralization of the skeleton generally, but not of the teeth. His observations regarding the teeth are, he says, in accord with those of H. Beraz (Zeitschr. f. Biol. Vol. 17, p. 386.)

While the dry, fat-free weight of the skeleton decreased, that of the teeth increased during the feeding of oats, with calcium sulphate in one case and tricalcic phosphate in another.

It is of interest to note that the administration of calcium phosphate with the oats did not prevent a loss in the dry, fat-free weight of the skeleton.

Weiske has also shown, by administering dilute sulphuric acid or monosodium phosphate in the food, to rabbits and sheep, that the percentage of ash in the bones could be decreased. By continuous feeding of cereals, for protracted periods, to mature herbivora, he also produced demineralization of the skeleton.

In unpublished experiments by the author, with swine, in the comparison of the nutritive values of various compounds of phosphorus, malnutrition of the bones has been caused by insufficiency of mineral bases to neutralize the mineral acids present. A low-phosphorus basal ration, supplemented with hypophosphites, produced acute disturbance of nutrition, as shown by great lameness, stupor, excessive fatness, minimum increase in weight of muscles, maximum percentage of fat in the increase, decided loss in breaking strength and in ash per cubic centimeter and in total weight of ash of the bones. This ration produced knob-like swellings at the point of union between the ribs and their cartilaginous extensions and required modification in order to keep the pigs alive for fifty-six days.

The same basal ration, supplemented by glycerophosphates of the same mineral bases, produced great increase in the size, breaking strength and total ash in the bones and also in the ash per cubic centimeter of bones. There was also a maximum increase in the weight of the muscles and a minimum percentage of fat in the increased weight, and the pigs throve exceedingly. These differences, in so far as they relate to the bones, are due largely to the greater proportion of acid to base in hypophosphites than in glycerophosphates; and as they relate to muscular development, are due to the fact that glycerophosphates are useful in muscular growth, while hypophosphites will not sustain development of these tissues.

In earlier work the author found that water-extract of wheat bran, which contains an abundance of phosphorus as calcium-magnesium-potassium-phytate, had the capacity greatly to strengthen the bones of pigs and to contribute to the growth both of bones and muscles, but when this food was used in excess it caused, probably through an excess of acid mineral elements contributed to the ration, pathological symptoms and much less increase in the growth of bone and muscle.

"Bran disease," "shorts disease" or "miller's horse rickets" is in all probability malnutrition of the bones, possibly combined with acidosis, due to lack of calcium in the food, and perhaps to a superabundance of acid mineral elements; possibly also to an excess of magnesium.

It is very well known by all intelligent swine-breeders that corn alone does not produce maximum growth of bone. The fact has also been proven, many times over, by a large number of experimenters in the field of animal husbandry, especially by Henry, of Wisconsin, and by thousands of stock-raisers in every-day practice, that the addition of mineral matter, either in other foods or by itself as in wood-ashes or bone-meal, is beneficial to bone formation and also, to some extent, to structural development generally.

This deficiency of corn in mineral matter is due to a lack of mineral bases generally and to lack of calcium especially, and probably also to a lack of phosphorus. It is possible that unfavorable effects are also due to an excessive proportion of magnesium in relation to calcium. In bone there is 86 times as much calcium as magnesium and in the body generally about 40 times as much, while in corn there is ten times as much magnesium as calcium. Certain evidence lends support to the idea that this disproportion of calcium to magnesium in corn may be a matter of importance. In our experiments corn alone has produced weak bone and little muscle, while the addition of protein and mineral matter, in the shape either of organic or inorganic phosphates, has proven quite effective to cause increased capacity to produce bone and muscles. Feeding on corn alone often results in the "breaking down" of fat hogs on the way to market and of brood sows upon the farm. Show hogs often exhibit symptoms of a similar weakening of the tendinous attachments when "let down" too rapidly after the show season and hogs being fitted for show are often "fed off their feet," as the saying goes, by crowding them along too fast on foods which contain a deficiency of mineral bases (especially calcium) in relation to the acid mineral elements present.

MALNUTRITION OF THE BONES.

These above cases of malnutrition of the bones are the results of two factors, (1) lack of bone-forming constituents and (2) an excess, either absolute or relative to mineral bases, of acid mineral elements.

These same factors receive consideration as contributory causes of osteomalacia, rickets and osteoporosis, diseases in which malnutrition of the bones is a prominent symptom, though malnutrition is by no means the sole cause of these difficulties.

Rickets and osteomalacia are diseases involving various tissues; among others, the bones. In rickets demineralization occurs through a loss of capacity, by the bone-forming tissue, of the power of absorbing and assimilating calcium. In osteomalacia there is a loss of the power of the bones to retain calcium. The cause of

neither disease, as it occurs in human beings, is known. While these diseases often follow deficiency of the food in calcium and phosphorus, this is by no means the only cause and in human beings, at least, apparently not the fundamental one, especially in rickets.

Osteomalacia. In osteomalacia it appears that the carbonates are not removed from bone more rapidly than the phosphates.

Magnus-Levy[32] found in the bones of a woman who had died from osteomalacia that the calcium and phosphorus decreased in the same ratio, one to another, as that in which they occur in normal bone. In treating fresh, normal bone with lactic acid, much more of the carbonate dissolves out than of the phosphate.

Mohr[33] says regarding metabolism in osteomalacia, "It is an important fact that the loss of mineral matter affects all the constituent elements equally and not the calcium especially."

Thus it is apparent that the loss of mineral matter from the bones in osteomalacia is directly due to autolysis and not to solution in free acids.

Veterinary writers usually say without qualification that osteomalacia is caused by lack of mineral salts in the food. Thus Atkinson and Mohler[35] say, "The cause of this affection is the insufficiency or total absence of lime salts in the food, also to feeding hay of low, damp pastures, kitchen slops and potatoes, or to overstocking lands. It occurs on old, worn-out soil, devoid of lime salts, and has been observed to follow a dry season. The disease in this country is confined to localized areas in the Southwest, known as the "alkali districts," and to the old dairy sections of New York."

In the 15th Annual Report of the Bureau of Animal Industry, 1898, p. 530, osteomalacia is reported as common in Texas, especially in dry summers. The cause is here stated to be an insufficient supply of certain mineral ingredients in the food, probably phosphates of lime.

Law[36] speaks of the prevalence of the disease in damp lowlands of Belgium and Jutland, in the Swiss valleys, on the damp lands of New Jersey and the Carolina seaboard, and generally on damp pastures with rank, watery herbage.

A large number of agriculturists and veterinarians, in Europe and in South Africa, also believe that the cause of osteomalacia is a deficiency of the herbage in calcium and phosphorus, either because of natural poverty of the soils in these elements, as in parts of South Africa, and in certain regions in the Hawaiian Islands, or because of abnormally low calcium and phosphorus contents of the forage on worn lands, following a dry season.

The above ideas as to causes of osteomalacia in live-stock are easily harmonized.

In dry seasons the minerals in the forage are deficient because of diminished transpiration of water. In dry regions we have the same condition present. Scanty food, due either to drought or to over-stocking of the pasture, also limits the amount of mineral nutrients available to the animal. On soils naturally deficient in lime or phosphorus, or on those depleted by tillage, the forage is low in these elements. On abnormally damp pastures or poor lands a low mineral intake might be explained simply by the bulky character of the watery grass. Then too its laxative character would interfere with the utilization of its nutrient constituents. The author has seen chinch bugs thrive exceedingly in an insectary on scantily watered corn, while they drank themselves to death on the dilute sap of generously watered plants. Animals most likely to suffer from osteomalacia are colts, cows with the first calf and heavily producing milk cows.

The symptoms, according to Atkinson and Mohler[35], are "a gradual emaciation and symptoms of gastro-intestinal catarrh, with depraved appetite, the animal eating manure, decayed wood, dirt, leather, etc. Muscular weakness is prominent, together with muscle tremors, which simulate chills, but are not accompanied by any rise of temperature. The animal has a stiff, laborious gait; there is pain and swelling of the joints, and constant shifting of the weight from one leg to another. The restricted movements of the joints are frequently accompanied by a crackling sound, which has caused the name of "creeps" to be applied to the disease. The coat is dull and rough and the skin dry and hidebound. The animal is subject to frequent sprains or fracture of bones without apparent cause, as in lying down or turning around, and when such fractures occur they are difficult to unite. The bones principally involved are the upper bones of the legs, the haunch bone, and the middle bones of the spinal column."

Friedberger and Fröhner[37] consider that, in live stock, there is a close relationship between osteomalacia and rickets and speak of rachitis as "a form of osteomalacia due to special conditions of growth of the young bone."

They consider an insufficient quantity of calcium in the food, either from deficiency of the soil in calcium, or from climatic influence, to be a cause of this disease.

Bran disease of horses they describe as but a form of rickets and also say that in old animals it is identical with osteomalacia.

In this disease there are bony enlargements about the articulations of the knees and tarsus and changes appear in the bones of the head, including loss of the teeth. The disease may result fatally.

Friedberger and Fröhner speak of rickets as being especially common in young pigs and dogs and state that its dominating cause is want of calcareous salts in the food.

Prominent among the anatomical symptoms are congestion and thickening of the periosteum; the bone becomes covered with exostoses, especially at points of muscular attachment; muscular contractions may remove the thickened periosteum; profound changes also occur at the ends of the long bones which result in abnormal growth of the cartilage and in various deformities. In live-stock this disease responds readily to treatment with calcium phosphate, which may be supplied mixed with salt. A change of ration to one containing an abundance of calcium is also of decided benefit.

Osteoporosis. This disease appears to be distinct from osteomalacia. Its cause is unknown. It does not respond to medication with calcium phosphate and is not caused by deficiency of the food in calcium and phosphorus, though this may be a contributory cause.

Mohler[38] says of this disease: "In the southwest, where osteomalacia or "creeps" has not infrequently been observed by the writer among range cattle, no case of osteoporosis of the horses using the same range has been noted, although the latter are given no more care or attention than the cattle."

"Osteoporosis is a general disease of the bones which develops slowly and progressively and is characterized by the absorption of the calcareous or compact bony substance and the formation of enlarged, softened and porous bone. This fragile and deformed condition is particularly manifest in the bones of the head, causing enlargement and bulging of the face and jaws, thereby giving rise to the terms "big head" and "swelled-head" which are applied to it. The disease affects horses, mules and asses of all ages, classes, breeds, and of both sexes, but is probably more frequently observed in mature horses and Shetland ponies. The disease is found under all soil, food and climatic conditions."

The terms "osteoporosis" and "big-head" have also been used by A. W. Bitting[39], of the Florida Station, to apply to the same disease.

There is some confusion in literature regarding the application of the term "osteoporosis" for Mohr[34] uses it to apply to experimentally produced fragility of the bones caused by the administration of lactic acid or of foods containing no lime.

Hammarsten[40] referring to the experiments of E. Voit uses the term "osteoporosis" to apply to rachitic changes in bones of young animals, caused by lack of calcium salts in the food.

In this country we use "osteoporosis" to signify a definite disease, especially of horses, which is not caused by a lack of lime salts in the food. This use of the term is also so general elsewhere among veterinarians, that it should be restricted in its application to this communicable disease.

H. Ingle,[41] writing from Transvaal, reports analyses of the bones of horses, mules and asses which had suffered from osteoporosis. He found the ratio of nitrogen to ash to be 1:10.8 in bones of animals which had suffered from this disease and 1:14.37 in sound bones. The relation of phosphorus to calcium was the same in both cases.

Ingle considers that the cause of the disease is the low proportion of calcium to phosphorus in the oat-hay and Indian corn which compose the usual ration for these animals in Transvaal.

From Laws and Gilbert's analyses he concludes that the amounts of lime and phosphorus pentoxide in the ash of foods should be about equal. In the ash of South African oat-hay he finds the proportion of phosphorus pentoxide to lime to be as 100:51 and he quotes Wolff's analyses showing the proportion of phosphorus pentoxide to lime to be in Indian corn as 100:4.

Ingle also notes the fact that the ash of wheat bran contains phosphorus pentoxide and lime in proportion of 100:9 and considers its poverty in lime to be the cause of "bran rachitis," "bran disease" or "miller's horse rickets." The evidence, however, does not sustain Ingle's belief that deficiency of the forage in calcium is the primary cause of osteoporosis.

D. Hutcheon, Chief Veterinary Surgeon in Cape of Good Hope, whose abundant experience with osteomalacia in South Africa leaves him with the conviction that this disease is caused by deficiency of the food in bone-forming constituents, and who has found that it responds readily to medication with salts of calcium and phosphorus, insists that the osteoporosis of horses is an entirely distinct malady and that it is not caused primarily by deficiency of the food in calcium salts; further, he finds that it does not respond to treatment with bone-meal as does osteomalacia. It is apparently a communicable disease though the method and cause of infection are unknown.

Hutcheon distinguishes between the effects of these diseases upon the bones in part as follows:

"In osteomalacia the diseased bones retain their normal size and external appearance, but there is a softening of the walls of the bones, with slight enlargement of the medullary spaces, the marrow in which becomes highly vascular, and an increase in the cancellous tissue toward the ends of the long bones."

"In osteoporosis the affected bones are enlarged, their tissues soft and elastic and their honeycomb structure full of extravasated blood. The osseous tissue is pink, soft, easily cut with a knife, is spongy, elastic and yields blood upon pressure. The Haversian canals are greatly enlarged and filled with gelatinous exudate."

The most that can be said relative to remedial treatment is that a change of conditions and surroundings often affects a cure even in cases that have become severe.

THE HUMAN DIETARY.

This subject is of importance in human nutrition because of its bearing upon the matter of diet in diseased conditions and because of possible cumulative effects upon the development of the tissues through slightly abnormal conditions long sustained.

This generation of Americans, at least, feed themselves a superabundance of protein, especially in the form of meat. Meat does not contain enough mineral base to neutralize the mineral acids which may be produced from it in the body.

Vegetables and fruits are, because of their great excess of basic over acid mineral elements, much better suited to supplement meat than are the cereal preparations, none of which have any considerable preponderance of mineral base, while in most, the balance is in favor of mineral acid.

White bread has an excess of acid minerals and so have corn and most of our multitudinous, prepared breakfast foods.

This overconsumption of protein, especially in meat, coupled with our increasing use of cereal preparations and of sugar, which supplies carbohydrates without basic mineral matter, requires of us that we give attention to those foods which are by nature fitted to supplement this one-sided ration. Such foods are vegetables, especially, and also fruits.

We do not have definite evidence upon the strength of which to assert that a failure to consider this matter has led to the development of weak bones and poor teeth in human beings, but since the skeletons of other animals may be ruined by a very few weeks' feeding of these animals on meat alone or cereals alone, we must in fairness to ourselves consider it at least a possibility that wrong habits in the choice of food, especially for children, may in the course of the growing period unfavorably influence the development of the bones.

The liking for vegetables often requires to be cultivated in a child and not all children care for milk. Two such have come to the author's notice. Fortunately they are fond of fruit. Without fruit or vegetables or milk it would be difficult to satisfy a child with foods which provide a sufficient excess of mineral base over mineral acid, to insure the maximum growth of healthy bones.

It is easier and more comfortable to trust to instinct in these matters, but with our increasing independence in the choice of food, we must accept the burden imposed by our prosperity and learn rationally to shape our ways. Our interest in these matters is exactly similar to that of the traveller by foot who after having taken to an automobile, comes to have a new concern as to whether it is a field or a declivity over the hedge at the next turn of the road.

Where so many of the ills to which the flesh is heir are due to, or are influenced by, derangements of nutrition it seems that knowledge in this field should be a part of whatever system of living or education one may choose to follow.

Acidosis in infants. In infant feeding, acidosis is an exceedingly common source of trouble. The difficulty is most frequently met with in artificially fed infants.

Cow's milk supplies to the infant a greater amount of digestible protein in proportion to available alkali than human milk and hence the acids formed by oxidation of this protein will be greater in amount, relative to alkali available for their neutralization. This calls for ammonia to make good the deficiency.

Another factor in the causation of infantile acidosis is the high fat-content of cow's milk. Steinitz showed that the increased excretion of ammonium salts, on a milk diet rich in fat, was a consequence of the removal of alkali by way of the intestine. A part of the calcium, which normally would be excreted as calcium phosphate, forms a difficultly soluble calcium soap with fats of the food, and is then excreted in the feces. Either excess or indigestible character of the fat in the food may cause this increased elimination of alkalis in the feces, which, together with the consequent increased ammonia excretion by the kidneys, constitute the two most prominent indications of acidosis.

The use of skim milk, butter-milk, barley gruel, orange juice and egg albumen tend to alleviate symptoms of acidosis by virtue either of low fat-content or predominance of basic over acid mineral elements.

The limited capacity of young animals to tolerate fat in the food is a matter of common observation among stockmen. Cattle raisers commonly believe that calves thrive better on Shorthorn or Holstein

milk than upon richer Jersey milk, and successful showmen commonly use as nurse cows, individuals of the breeds which yield milk relatively low in fat.

As bearing upon the feeding of infants we would call attention to the fact that selection has increased the fat-content of the Jersey cow's milk until even her own calf will thrive better on the milk of some other breed which yields milk that is not so rich in fat.

The writer once saw a thousand-pound Shorthorn steer calf which was being fitted for show, put onto a Jersey nurse cow which produced two pounds of butter-fat per day. For months the steer was a light eater and the slightest irregularity or change of food would throw him "off-feed." After the discontinuance of the services of his butter-producing foster-mother, he throve exceedingly. It is possible that acidosis is caused by such an excess of fat through its combination and excretion with calcium in the intestines.

Czerny and Steinitz[43] note that Keller in studying children suffering with gastro-intestinal complaints found in the urine almost invariably an abnormally high ammonia excretion, amounting to 52 percent of the total nitrogen, and that Van der Bergh gave sodium bicarbonate to infants suffering from digestive disturbances with the result that the ammonia excretion immediately decreased in a very marked manner.

Czerny and Steinitz conclude that this increased ammonia excretion in the urine of children suffering with digestive disturbances indicates the presence of acids and is formed for the purpose of their neutralization and not because of defective urea synthesis by the liver.

Czerny and Keller find that, among the various foodstuffs, fat alone leads to an increased excretion of ammonium salts in the urine.

Keller[44] finds that free acids are not excreted in the urine of children suffering with gastro-intestinal disorders but that they are eliminated in combination with ammonia.

Steinitz concluded that a diet of milk which was rich in fat might exercise an unfavorable influence upon the growth of children suffering from gastro-intestinal troubles through causing a loss of alkalis, which are essential to normal development.

Acidosis may also be caused in infants by too strict an adherence to a cereal diet. Steinitz and Weigert[45] report the composition of the body of a four-months-old child which died as a result of an exclusively cereal diet. The composition shows the body to have lost a large part of the sodium, potassium and chlorine normally present.

Czerny and Steinitz say, "The importance of relative acidosis in chronic disturbances of nutrition in infants lies in the loss of alkali.

For the growth and health of the child's organism the retention of alkali is as important as the retention of nitrogen, phosphorus, or other mineral substances. If it is withheld, or a loss takes place, the condition of the body can neither improve nor remain normal."

MINERAL BASES AND ACIDS IN FOODS.

For the sake of convenience in this discussion we use the term "ash" to signify a combustion residue in which all of the acid-producing mineral elements of the fresh substance are present. Unfortunately we have not access to any considerable number of analyses of foodstuffs which accurately indicate the amounts of the mineral elements contained, since almost all of the available determinations have been made upon the ash, which does not contain all or nearly all of the mineral matter of the fresh substance.

Sulphur especially is largely lost during ashing, even if this is carefully done. Other elements may also volatilize in this process. The loss is much more likely to decrease the total mineral acid present than the total mineral base and the loss is greatest in those products where mineral acids predominate.

Hence in order that the following figures may not mislead it is necessary to consider them as but most general indications of the truth, except where we know that adequate means were used for the estimation of the total amounts of the minerals present in the fresh substances.

The errors are quite misleading in the case of the cereals and cereal by-products. The excuse which we have to offer for using these analyses for a purpose which they serve so imperfectly is that they are the best available at this time; they do indicate some general truths of importance and their use for this purpose should serve to call the attention of other workers in the same field to the great desirability of making accurate mineral analyses of our foodstuffs. The amount of labor involved in such work is very considerable but we shall be able eventually to substitute more accurate figures for these which we have compiled.

In order to indicate what the loss in acid mineral elements in ashing may signify, let us examine the figures for gluten flour, No. 31 in the table on page 44.

In this foodstuff, Mr. A. C. Whittier of this laboratory, found 8.39 parts of ash per 1000 parts of dry substance, by an approved method involving the leaching of the charred substance. Sulphur was determined by fusion with sodium carbonate and sodium peroxide over an alcohol lamp and the amount of sulphur found was 10 parts per 1000; a greater quantity than was found of all the mineral elements together, in the ash.

MINERAL CONSTITUENTS OF VEGETABLE AND ANIMAL FOODS.—Parts per 1000 of Dry Substance.

		Moisture	Ash	Potassium	Sodium	Calcium	Magnesium	Phosphorus	Sulphur	Chlorine	C. C. Normal Solution, 1000 Grams				Authority for Analysis
											Total Base	Total Acid	Excess Base	Excess Acid	
1	Cow's milk........	873.0	56.7	11.60	3.44	9.09	.88	6.50	.57	7.91	971.14	678.0	293.1	.....	K. II, 603
2	Woman's milk	876.0	24.2	6.79	1.65	2.88	.31	2.40	.18	4.45	414.11	291.6	122.5	.....	K. II, 598
3	Sow's milk	840.0	68.6	3.53	3.42	19.23	.74	11.13	.36	6.40	1258.40	921.1	337.3	.....	K. II, 602
4	Ewe's milk........	855.0	69.0	13.95	2.30	15.34	.59	9.10	.39	5.24	1269.6	759.2	510.4	.....	K. II, 602
5	Black Albumen...	74.6	35.7	2.38	11.67	.41	.17	.95	7.03	12.32	724.6	847.4	.....	122.8	Whittier
6	Beef	758.0	....	15.12	2.69	.08	.99	7.02	3.10	2.36	588.2	712.9	.....	124.7	Katz
7	Pork	729.0	....	9.37	5.76	.30	1.03	7.86	3.02	1.77	588.8	745.4	.....	156.7	Katz
8	Chicken	684.0	....	14.72	3.00	.35	1.17	8.01	3.70	1.90	619.7	801.2	.....	181.5	Katz
9	Eggs...............	734.0	34.8	5.55	4.53	2.10	.51	5.78	.13	4.85	484.9	517.8	.....	32.9	W. I, 158
10	White of egg	856.0	46.1	12.02	10.80	.92	.77	.89	.39	13.29	884.7	456.6	428.0	.....	W. I, 158
11	Potatoes	750.0	37.9	18.90	.83	.72	1.13	2.79	.99	1.31	647.5	278.7	368.8	.....	K. II, 898
12	Sweet Potatoes....	700.0	30.7	12.82	1.49	2.18	.63	1.42	.68	3.91	552.6	244.3	308.2	.....	K. II, 902
13	Beets, red.........	880.5	59.7	8.44	21.60	2.49	.11	2.56	.50	2.94	1285.9	279.3	1006.6	.....	W. I, 182
14	Turnips............	868.0	80.1	30.20	5.85	6.07	1.79	4.45	3.59	4.06	1474.9	625.6	849.3	.....	W. I, 156
15	Tomatoes	962.0	260.5	82.50	32.93	11.36	13.57	10.73	4.98	18.05	5216.6	1512.1	3704.5	.....	A. & N., 236
16	Onions	865.0	52.8	10.98	1.25	8.29	1.68	3.46	1.16	1.46	886.1	336.8	549.3	.....	K. II, 919
17	Cabbage, heart...	871.0	108.5	25.10	8.05	16.63	2.34	7.11	3.72	8.53	2011.9	931.4	1080.5	.....	M. & Von L., 1905
18	Asparagus........	937.0	72.6	14.49	9.21	5.63	1.89	5.89	1.79	4.31	1205.6	613.3	592.4	.....	K. II, 924
19	Spinach...........	892.0	164.8	22.67	43.18	13.98	6.34	7.38	4.53	10.37	3670.2	1051.3	2618.9	.....	K. II, 929
20	Rhubarb..........	959.0	144.4	71.45	5.52	10.37	....	9.28	1.10	7.75	2581.7	886.0	1695.8	.....	W. II, 128
21	Oranges...........	843.0	30.8	9.31	3.06	5.40	1.50	1.49	.46	.72	763.9	145.1	618.8	.....	W. II, 124
22	Apples	840.0	14.4	4.27	2.79	.42	.76	.85	.35	....	313.5	76.7	236.8	.....	W. I, 126
23	Plums.............	786.0	20.8	11.98	.36	.60	.61	1.19	.20	.07	401.6	91.2	310.4	.....	K. II, 959
24	Raisins............	261.0	28.6	11.05	1.57	1.09	.98	2.23	.69	1.39	585.2	226.9	259.1	.....	A. & N., 237
25	Figs...............	789.0	29.2	13.54	.52	2.27	.99	1.63	.46	.60	562.9	150.8	412.1	.....	K. II, 959
26	Apricots...........	842.0	42.1	21.95	3.35	.89	.79	2.03	.43	.18	815.3	162.9	652.4	.....	K. II, 959
27	Wheat, grain......	144.0	20.8	5.04	.26	.41	1.41	4.08	.09	.56	276.2	285.3	....	9.1	M. & Von L., 1905
28	Wheat bran.......	.....	61.6	14.58	.30	1.27	6.22	13.54	.02	....	959.4	874.8	84.6	.....	W. II, 126
29	White bread	355.0	21.5	1.25	3.14	....	.29	1.58	1.25	6.53	192.0	364.1	....	172.2	A. & N., 227
30	Graham bread....	412.0	26.6	3.21	2.86	1.08	.75	2.48	.22	6.41	319.0	354.5	....	35.5	A. & N., 229
31	Gluten flour.......	70.5	8.4	.47	.43	.90	.59	1.96	10.00	.38	123.6	200.0	....	75.9	Whittier
32	Rice, hulled.......	121.0	3.9	.70	.16	.09	.26	.91	.01	.004	50.7	59.4	....	8.8	W. I, 154
33	Oat meal..........	98.0	18.3	3.61	.56	.97	.86	3.85	.05	.98	236.4	279.2	....	42.8	K. II, 834
34	Oats, grain	143.0	32.0	4.65	.35	.84	1.34	3.77	.23	.35	285.9	267.5	18.4	.....	M. & Von L., 1905
35	Corn, grain	133.0	14.5	3.59	.12	.23	1.36	2.89	.05	.13	219.8	192.9	26.9	.....	K. II, 775
36	Corn, grain	120.8	15.5	3.20	.52	.11	1.25	3.36	1.60	.45	212.3	329.3	....	117.0	Whittier
37	Corn bran.........	77.5	13.3	2.60	.00	.33	.82	1.24	.76	.42	150.3	139.3	11.1	.....	"
38	Pearl hominy	111.8	4.05	1.08	.12	.05	.21	.55	1.36	.54	52.1	135.6	....	83.4	"
39	Beans	140.0	36.3	12.50	.29	1.30	1.57	6.16	.49	.65	525.6	446.3	79.3	.....	K. II, 784
40	Soy beans.........	78.9	31.4	11.62	.23	1.19	1.69	5.06	.34	.08	504.9	349.9	155.0	.....	W. II, 34
41	Cottonseed meal ..	.....	74.8	18.48	.....	2.36	6.86	15.01	.37	.03	1153.0	992.3	160.6	.....	W. II, 127
42	Linseed oilmeal ...	122.0	58.4	11.82	.68	3.50	5.51	8.06	.78	.46	963.3	581.6	381.7	.....	M. & Von L., 1905
43	Corn stover	150.0	53.3	16.02	.44	4.15	1.85	1.54	1.13	.94	787.2	196.4	590.8	.....	" " " "
44	Oat straw.........	143.0	70.8	13.57	1.73	3.59	1.62	1.53	.93	4.67	733.7	288.4	445.3	.....	" " " "
45	Timothy hay......	143.0	68.3	19.67	.95	3.92	1.34	3.51	.79	3.50	849.2	374.5	474.7	.....	" " " 1888
46	Red clover hay....	160.0	68.6	18.38	.97	17.11	4.53	2.89	.90	2.62	1736.9	316.5	1420.4	.....	" " " 1905
47	Alfalfa hay	160.0	73.8	16.41	.97	21.44	2.23	3.38	1.72	2.98	1713.7	409.4	1304.2	.....	" " " "
48	Rape, green,......	870.0	80.8	22.35	2.29	12.64	1.86	4.03	4.62	6.15	1453.4	721.7	731.7	.....	" " " "

The analysis of corn, No. 35, from König, is as satisfactory as any we were able to find in literature. A comparison of these figures with those of A. C. Whittier for the same product, No. 36, gives further illustration of the loss of minerals in ashing.

Thus it is apparent that final judgment as to the balance between basic and acid mineral elements in cereals must be withheld until warranted by further analytical work.

The analyses in the table on page 44, followed by the initial "K" are from König's "Chemie der menschlichen Nahrungs-und Genussmittel;" those ascribed to Katz are from Arch. ges. Physiol., vol. 3, p. 14; those followed by the initial "W" are from Wolff's "Aschen Analysen," "A. & N." signifies Albu and Neuberg's "Mineralstoffwechsel," "M. & Von L.," Mentzel and Von Lengerke's landwirtschaftliche Kalender and those by A. C. Whittier are from this laboratory. In these last, the sulphur determinations were made by fusion of the fresh substance.

In this table on page 44, we state the amounts of the various mineral elements contained in 1000 parts of dry substance. In the third and fourth columns of figures from the right, we state the total amount of acid minerals and of basic minerals computed to normal solutions, that is, so that one cubic centimeter of acid will exactly neutralize one cubic centimeter of base. Phosphoric acid is considered to be neutralized when two of its hydrogen atoms are replaced by a base.

In the two columns on the right side of this table is stated the excess of acid or base, as the case may be, in cubic centimeters of normal solution in 1000 grams of dry substance. To reduce any of the figures to the fresh or air-dry basis, multiply the numbers as stated by the dry substance expressed as percent.

This excess of acid or base as stated in the table is obtained by subtracting the total amount of acid (phosphoric, sulphuric and hydrochloric) from the total amount of base, (sodium, potassium, calcium and magnesium.)

Thus we ascertain the nature of the active or unsatisfied excess of mineral matter, that is, whether it is base or acid. The rest is like a balanced account, debits equaling credits.

The excess, if of alkali, may be considered to represent carbonates or organic compounds such as upon oxidation yield carbonates of alkalis (sodium or potassium) or of alkaline earths (calcium or magnesium); if of acid it may be considered to represent acid-reacting elements such as upon oxidation yield free mineral acids.

In spite of the wide range of variation which there is in the composition of the ash of organic substances, in accordance with differences in species or environment, a general agreement as to balance between acid and basic minerals in foodstuffs of the same class, is apparent.

From these figures it would appear that the ash of milk is markedly alkaline and from this it is probably safe to conclude that the food of animals should possess an excess of mineral bases in the ash. This assumption seems particularly justifiable when we consider the fact that on the basis of Lawes and Gilbert's work, mineral base predominates in the ash of animal bodies and further when we consider the probability as shown by Soxhlet[46] that the calcium content of milk constitutes the limiting factor in the production of growth and that the storage in growing animals is more largely of basic than of acid mineral elements.

Black albumen, No. 5 in the table, a packing-house by-product, is the first separation of serum from blood-clot in the preparation of the clear, dried serum used in dyeing. We use this black albumen as a low-phosphorus proteid in nutrition experiments. It is rich in sodium, magnesium, sulphur and chlorine and has an acid ash.

Beef, pork and chicken flesh all have acid ash and Sherman calls attention to the fact that carnivora make good the deficiency of mineral base in flesh by the consumption with it of parts of the bones. As an only food, flesh undoubtedly possesses an excess of acid mineral elements.

The white of egg has a strongly alkaline ash while the ash of eggs as a whole, without the shell, is slightly acid.

We should not argue, however, that because mineral acids slightly predominate over mineral bases in eggs, animal food should possess a like excess of acid, since the egg is not food in the sense in which milk is food. The egg is potentially a complete being in itself, merely requiring transformation into the more highly specialized tissues of the fully formed animal and maintenance during the process. There is neither the necessity nor the provision, as in milk, of adaptation to the processes and activities of the digestive tract of the animal to be nourished.

Fruits and vegetables have, without exception, strongly alkaline ash. Their natural acidity is due to organic acids which are oxidized in the body and excreted as carbon dioxide and water.

Beets, cabbage, rhubarb, spinach and tomatoes have exceedingly alkaline ash, the excess of alkali ranging from one cubic centimeter of normal solution in beets, to three and seven-tenths cubic centimeters per gram of dry substance in tomatoes.

Potatoes, onions and asparagus are also conspicuously basic as to ash, but in a class decidedly second to beets, cabbage, rhubarb, spinach and tomatoes.

Fruits also are unmistakably basic as to ash, apricots and oranges containing considerably more than half a cubic centimeter of excess normal base per gram of dry substance, while figs come a little under this mark and apples, plums and raisins are in a second class as regards alkalinity of the ash.

Of the cereals, wheat appears to be slightly acid, as are also white bread and graham bread, gluten flour, corn, pearl hominy and oat meal. Further work will doubtless show that the measure of acidity in most of these cases is low. Oats here appear to have an alkaline ash, doubtless due to loss of acid minerals; corn bran has a slightly alkaline ash and wheat bran is, on the basis of the evidence at hand, doubtful as to reaction of the ash. The cereals are usually considered to have an acid ash and as is well known, do not support normal growth of bone.

Magnus-Levy[6] says: "A part of the vegetable foods of man, the cereals, yield (just as does flesh) an acid ash, whereas the grasses and herbs of herbivora yield an alkaline ash. Cereals are equivalent to animal food in respect to the metabolism of the ash."

In corn there is a decided excess of acid minerals over basic minerals and the total ash of corn is also low. Both of these factors may contribute to the production of acidosis by corn, as also may the disproportionate excess of magnesium in comparison with the small amount of calcium present. As in corn, so in bran, the magnesium content is greatly in excess of the calcium, while, for structural purposes and for milk production, very much more calcium than magnesium is needed.

In spite of the richness of bran in mineral matter the existence of "bran disease" or "miller's horse rickets" indicates that its mineral nutrients are in a some way out of balance.

Mendel and Benedict[47] find that the injection into an animal of either calcium or magnesium salts, leads to an increased excretion of the other, (calcium if magnesium has been injected or the reverse), by the kidneys.

J. Malcom[48] comes to the conclusion that the ingestion of soluble magnesium salts causes a loss of calcium in adult animals and hinders its deposition in young, growing animals, but that soluble calcium salts do not in the same way affect the excretion of magnesium.

Beans, soja beans, linseed oilmeal and cottonseed meal are all high-proteid foods and their sulphur contents should be correspondingly high. The evidence hardly warrants drawing conclusions as to the balance of minerals in the ash of these foods.

The various hays and straws appear to have strongly alkaline ashes. Clover and alfalfa, however, largely because of very high lime contents, have much more alkaline ashes than have the grass plants.

While it is universally recognized that clover or alfalfa, with corn, constitutes a ration, for farm animals, which cannot be greatly improved, especially for the production of increase in weight, still it is not so generally understood that the high content of these legumes in mineral bases generally and calcium in particular, constitutes an important factor in the superiority of these feeds as supplements to corn. This, however, is undoubtedly true since these legumes are characteristically rich in those mineral nutrients which are lacking in corn.

A comparison of some of the above figures with recent work by Sherman and Sinclair[49] indicates that the estimates of the acid mineral elements of wheat, oatmeal and milk are probably decidedly low, though in each case the balance would remain on the same side of the account as indicated by the figures which we quote.

This balance between acid and base in foodstuffs may be modified, before these nutrients reach the tissues, by certain influences in the alimentary tract. Thus according to Albu and Neuberg[14] the amount of calcium absorbed from the intestine is influenced by the other salts present, sodium chloride increasing its resorption and alkalis diminishing it. The formation of difficultly digestible calcium soaps in the intestine may also alter the balance between the acids and bases resorbed. Further, variations in the solubility and resorbability of the salts in the various articles of the dietary tend to render definite conclusions difficult; and calcium from vegetable foods is much less completely absorbed than the calcium from flesh.

It is also impossible closely to estimate the proportion of the mineral bases that will leave the body in combination with organic acids in the urine. To be entirely accurate it would also be necessary that we leave out of consideration such portions of the organic sulphur and phosphorus of the food as leave the body in organic combination; also that we consider in a more definite way than is now practicable, such organic acids as leave the body in combination with mineral bases, and further that we consider the fact that some phosphorus leaves the body as acid phosphates, that is, without carrying

with it enough inorganic base to render it neutral. There is, however, a compensating factor, since some phosphorus leaves the body carrying more than enough mineral base to render it neutral.

Is it a matter of importance whether this balance be maintained at a high or a low level? The excess of either acid or base might be the same in a food very poor in both as it is in one very rich in both.

In answering this question we must bear in mind the fact that excess of acid or base is but one of the many factors affecting the usefulness of the mineral elements as animal nutrients. All of those minerals which are of use in the body as neutral inorganic salts, might be withdrawn from a ration without altering in the slightest degree the excess of either acid or base. The great majority of the functions of the mineral elements in the body are served in accordance with the amounts and kinds of minerals present, and quite irrespective of any excess of bases or of acids, unless such excess interferes with normal processes. (See note.) Thus it appears that it is a matter of great importance that the balance be maintained at a high level rather than at a low one.

SUMMARY.

The organic acids of foodstuffs, such acids, for instance, as the citric, malic and tartaric acids of fruits, are mostly oxidized in the animal body to carbon dioxide and water, in which compounds they are excreted; but there are formed within the body, mineral acids which cannot be decomposed and eliminated in this way. These acids must be neutralized in order to protect the animal from a disturbance of conditions essential to the continuance of vital reactions.

These acids are formed chiefly by the cleavage and oxidation of the proteids, either of the body or of the food, the sulphur and phosphorus contained therein, as constituent parts, being oxidized to the corresponding inorganic acids.

These acids are neutralized,

(1) by carbonates of the food, water or tissues;
(2) by alkalis liberated by the oxidation of organic-acid salts;
(3) by ammonia withdrawn from the constructive formation of urea;
(4) by ammonia from the tissues;
(5) by ammonia splitoff from proteids, especially for acid-neutralization.

Both acid and base are also liberated in slight amounts by the decomposition of sodium chloride in the formation of gastric juice.

NOTE: For information relative to the amounts of the various mineral elements required by animals the reader is referred to Kellner's "Ernährung der landwirtschaftlichen Nutztiere," to Von Noorden's "Metabolism and Practical Medicine" and to Bul. 201 of this Station.

The continued neutralization of excessive amounts of acids by some of these means, especially by use of the carbonates of the bones, may mould the whole style of development of a growing animal; may cause serious states of malnutrition and may act as contributory causes of a number of diseases of both Man and other animals.

In case the acids formed within the body or introduced into it exceed the animal's capacities to neutralize them, death may ensue with symptoms of asphyxia, or suffocation, due to disturbance of the equilibrium of salts of the blood plasma, upon which depends the capacity of the blood to carry carbon dioxide from the tissues to the lungs.

The practical bearing of the subject is on the feeding of such animals as are reared most largely on cereals, namely, swine and poultry; especially on the growth of the bones of animals; on acidosis in infants; and on the care of sufferers from rickets, osteomalacia, osteoporosis, bran disease and diabetes.

In this connection we consider especially the acid mineral elements, sulphur, phosphorus and chlorine, and the basic mineral elements, sodium, potassium, magnesium and calcium.

The relative amounts of mineral acids and bases formed in the body may be greatly modified by a choice of foodstuffs.

Fruits, vegetables, roughage and milk have alkaline ash; meat, eggs, cereals and many cereal foods and by-products have acid ash.

Corn has an acid ash and is also particularly deficient, as a food, in calcium and also in total mineral content.

In straight corn-feeding we see the resultant of a complication of deficiencies; corn lacks protein as well as minerals. In the ash, both acids and bases are deficient but the bases considerably more so than the acids, so that as an only food, corn is characterized by an excess of acid mineral elements and this excess, together with the deficiency in the total amount of mineral matter present, limits the growth of the skeleton; but if the protein in the ration of the corn-fed animal is increased by the use of supplements, to such extent as will support maximum production of proteid increase, then both phosphorus and the mineral bases must be increased.

The basic mineral elements in a ration must be present in quantities corresponding to the protein, since the sulphur and phosphorus of the food proteins constitute the principal sources of mineral acids in the body.

It is important not only that there be a considerable excess of mineral bases in the food but also that this excess be maintained at a high level, that is, that aside from the balance between acid and base, the total quantity of ash should be considerable.

The capacity of the animal body to neutralize and eliminate alkali seems to be entirely adequate. In practice animals do not experience injurious excess of alkali as they do excess of acid.

Consumption of a needless amount of protein unnecessarily taxes the acid-neutralizing capacity of the animal and if carried to a sufficient extreme, results either in discouragement of the formation of bone or in malnutrition of the bones.

A high fat-content, or indigestible character of the fat of milk fed to infants suffering from digestive disturbances, causes acid intoxication by withdrawal of alkalis, by way of the feces, in the condition of difficultly soluble calcium soaps.

Because of the alkaline ash of the milk of all animals, it is assumed that other food of animals should have an alkaline ash.

Any such circumstances, as drought, or poverty of the soil in calcium and phosphorus, as tend to diminish the content of the forage in these elements, at the same time limits the growth of the bones and favors the development of diseased conditions in the animals consuming them.

No animals which consume fruits, vegetables, milk or roughage in sufficient proportion to other food are likely to suffer from an excess of mineral acids in the body. Animals fed too little else than meat, eggs, and cereal foods, including bread, are more likely than others to suffer from an excess of inorganic acids or a deficiency of inorganic bases.

Growing animals, when fed for protracted periods on either cereals or meat alone, suffer from malnutrition of the bones, this ailment being caused by the deficiency of these foods in mineral bases.

Swine, because of their very rapid growth, have especial need for calcium in the food, as is indicated by the unusual richness of sow's milk in calcium. Corn contains less calcium than other common grain foods and on that account is less perfectly adapted to serve as an only food for swine.

Clover and alfalfa are especially rich in calcium and hence serve to make good the deficiency of corn in this element.

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PROTECTION OF FRUIT TREES FROM RODENTS

OHIO
Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., AUGUST, 1909.

BULLETIN 208

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BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 208 AUGUST, 1909

PROTECTION OF FRUIT TREES FROM RODENTS

By F. H. BALLOU

PREFACE

ACCORDING to the Official Report of the Ohio Department of Agriculture for 1907, there are, in the state, 266,340 acres of tree fruits including all classes. Of those classes more subject to tree injury by rodents, viz., apple, pear and plum, there are 247,700 acres. Of apples alone there are 243,716 acres. This great acreage includes not only the extensive commercial plantations, but the thousands of small, home orchards, scattered in every part of the state.

There are no data available which would render possible anywhere near a correct estimate of the loss of and injury to trees, young and old, through the work of rodents (mice, rabbits and woodchucks) in Ohio. While the loss is confined principally to newly set orchards, replants in older orchards and the younger plantations generally, this loss, in the aggregate, is considerable. It certainly would not be far beyond the bounds of conservatism to figure the loss and injury at one dollar per acre per year including all ages and conditions of the apple, pear and plum orchards of the state. The rate of loss would be less than this in the larger commercial plantations, even where the grass-mulch method of culture is practiced; for the commercial planter generally takes into consideration the various sources of danger and makes provision to

result from the use of rations of equal efficiency, pound for pound, in producing gains in live weight, do vary greatly on account of widely varying market prices of the feeds which constitute the rations. It is, then, obviously impossible to suggest a ration that will prove most profitable under all conditions. Results of feeding tests will show the efficiency of rations, but feeders will need to apply local market conditions to these results in order to select the ration that will give best financial returns.

In studying the efficiency of various rations care should be taken to compare only the results of experiments that were conducted simultaneously, as factors other than feed may cause wide differences in results secured from experiments that were conducted under conditions that were not identical in all respects except the rations used.

In all of these experiments, young, growing swine were used. It is entirely probable that the results obtained will not prove strictly applicable to the fattening of mature, thin swine. However, relatively few mature hogs are fattened nowadays, and the results secured will apply to most of the swine feeding operations as now carried on.

Corn was ground before being fed, except in the experiments with hogs in cattle feed-lots, when shelled corn was used. Ground feeds were mixed together and fed with sufficient water to form a thick slop. Daily rations were supplied in two equal portions. A mixture of salt and ashes was regularly kept before the swine during all experiments. All proportions indicated in the description of rations refer to the parts, by weight, of the different feeds used in the rations.

GRAIN RATIONS FOR FEEDING IN DRY LOTS.

Table I shows the results of an experiment covering 66 days in which four different supplements for corn were used, viz: soybean meal, wheat middlings, digester tankage and skim milk. While much more work will need to be done before definite figures representing the relative values of these feeds for supplementing corn may be secured, yet the table sets forth a number of facts that are useful in deciding what feeds to use in connection with corn, which will doubtless continue to be the chief grain used for fattening swine in dry lots.

Of the feeds used in connection with corn, skim milk gave the highest daily gain per pig. Wherever skim milk is available for pig feeding, it seems very improbable that any other feed

will supplement corn more completely, or that any ration will produce any more rapid and economical gains than will corn and skim milk. The chief difficulty with this ration is the fact that skim milk is not available for extensive use in the greater hog-producing sections. Nevertheless, wherever it is available, skim milk and corn will doubtless prove as efficient a ration as can be used for fattening swine. The rate of gain for the lot fed corn and skim milk was high—over two pounds daily per pig.

TABLE I: GRAIN RATIONS FOR FEEDING IN DRY LOTS.
6 Hogs in Each Lot. Experiment I, lasting 66 Days. February 13 to April 19, 1907.

Ration	Initial weight	Final weight	Gain	Average daily gain per pig	Total feed consumed	Average daily feed consumed per pig	Feed consumed per 100 lbs. gain
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Corn meal.....	534	743	209*	.571	1291	3.53	617.7
Corn meal, 4;.. Soybean meal, 1	533	959	426	1.075	1823	4.60	427.9
Corn meal, 1;.. Middlings, 1 ..	583.5	1078.5	495	1.250	2087	5.27	421.6
Corn meal, 6;... Tankage, 1,...	556.5	1195	638.5	1.612	2300	5.80	360.2
Corn meal, 1;.. Skim milk, 2.77	628.5	1199	684**	2.023	1983 corn 5505 s.m.	5.86 16.28	289.9 804.8

* One hog taken out March 20.
**One hog taken out February 21.

Digester tankage, a packing house by-product, ranked next to skim milk for efficiency in producing rapid and, from the standpoint of feed consumed for a pound of gain produced, economical gains. The amount of feed required to produce one hundred pounds of gain was comparatively small—360.2 pounds. The large amount of corn consumed daily per pig by the corn and tankage and the corn and skim milk lots is worthy of note. When either of these feeds was used, a much larger amount of corn was consumed daily than when a ration of corn alone, corn and middlings or corn and soybean meal was fed.

The lot which received corn and middlings, equal parts of each by weight, made fair gains and at a not exceedingly heavy expenditure of feed. The amount of feed consumed was much lower than for the corn and skim milk lot or the corn and tankage lot, and the amount of feed required for a given gain was relatively large. The relatively low consumption of corn is especially striking.

The lot which received a ration of corn, 4 parts; soybean meal, 1 part, failed to consume a sufficient amount of feed to produce very rapid gains. The low consumption of feed was due to the fact that the pigs did not relish the soybean meal and corn meal mixture. No pig in this lot gained more than 1.4 pounds daily. In later experiments at this Station corn and soybeans gave excellent results. (See page 76.)

When the results that were yielded by the lot fed corn alone are considered, it is not difficult to understand why many farmers find that hog feeding is not so profitable as it should be. The amount of feed consumed by this lot was small, the rate of gain was very low, and the amount of feed required to produce one pound of gain was very high as compared with any of the other four lots.

TABLE II: AMOUNT* OF PORK PRODUCED BY ONE BUSHEL OF CORN OR ITS EQUIVALENT. EXPERIMENT I.

Ration	Corn meal	Cornmeal, 1; Middlings, 1	** Corn meal, 4; Soybean meal, 1	Cornmeal, 6; Tankage, 1	Cornmeal, 1; Skim milk, 2.77
Pork produced by 100 pounds of feed, lbs.......	16.19	23.71	23.35	27.76	9.13
Cost of 100 pounds feed	$1.00	$1:125	$1.10	$1.14	$ .37
Amount of feed purchaseable for 56 cts., (the value of a bushel of corn.) lbs..	56.0	49.7	50.9	49.0	149.2
Pounds of pork produced from feed equal in cost to one bushel of corn.....	9.0	11.8	11.9	13.6	13.6

*Corn, 56 cents per bushel; middlings, $25.00 per ton; tankage, $40.00 per ton; skim milk, $3.00 per ton.

**See page 76 for result of second test of soybean meal.

It will be noted that a bushel of corn, as fed to Lot 1, produced only 9 pounds of gain. Had a portion of this corn been sold at 56 cents per bushel and the proceeds used to purchase supplemental feeds at the following prices: middlings, $25 per ton; soybeans, $30 per ton; tankage, $40 per ton; skim milk, $3 per ton, the amount of gain produced from one bushel of corn or its equivalent would have been 11.8, 11.9, 13.6 and 13.6 pounds respectively, as is shown in Table II. In other words, a given amount of money invested in corn and tankage or in corn and skim milk would have produced one half more gains than if invested in corn alone; and a much shorter time would have been required for this increased production. At the prices named, digester tankage and skim milk

would be equally efficient so far as amount of pork produced from a bushel of corn is concerned, but the rate of production was higher with corn and skim milk than with corn and tankage. Market prices vary greatly from time to time, and the above comparison is accurate only for the prices named.

TABLE III: COST PER 100 POUNDS PORK PRODUCED. EXPERIMENT I.

Price of corn per bushel	Corn alone	Cornmeal, 4;* Soybean meal, 1. (soybeans at $30 per ton.)	Cornmeal, 6; Tankage, 1. (tankage at $40 per ton.)	Cornmeal, 1; Middlings, 1. (middlings at $28 per ton.)	Cornmeal, 1; Skim milk, 2.77. (skim milk at $3 per ton.)
$ .28	$3.09	$3.00	$2.57	$4.01	$2.66
.35	3.86	3.42	2.96	4.27	3.02
.42	4.63	3.85	3.34	4.53	3.38
.49	5.40	4.28	3.73	4.80	3.74
.56	6.18	4.71	4.12	5.06	4.11
.63	6.95	5.14	4.50	5.32	4.47
.70	7.72	5.56	4.89	5.59	4.83
.77	8.49	5.99	5.27	5.85	5.19
.84	9.26	6.42	5.66	6.11	5.56

*See below for the results of a second test of soybean meal

Table III shows the cost of one hundred pounds of pork as produced in this test, with various prices for corn. The price of feeds other than corn would, of course, also have an important bearing on the cost of pork. The table is not presented with the thought that it will apply strictly to every case, but, rather, to show the great importance of considering cost of feeds as well as efficiency.

SOYBEANS COMPARED WITH TANKAGE FOR SUPPLEMENTING CORN IN DRY LOT FEEDING.

In two tests to compare soybeans and tankage as supplements for corn in dry lot feeding, the results shown in Table IV were secured. The advantage of both the corn and soybean and the corn and tankage rations over the ration of corn alone is very evident. It will be observed that soybeans made a much better showing in these tests than in a former one. No reason was apparent for the marked dislike which the pigs that received soybeans in the previous test showed for the corn and soybean mixture. While the experiments conducted at this Station indicate that pigs are not so fond of soybeans as of some other feeds, notably skim milk and tankage, yet the results of these two tests show an especially high value for soybeans as a supplement for corn.

TABLE IV: GRAIN RATIONS FOR FEEDING IN DRY LOTS.

5 Hogs* in Each Lot.—Experiment II lasting 84 Days. November 24, '08 to February 15, '09.

Ration	Initial weight	Final weight	Gain	Average daily gain per pig	Feed consumed	Average daily feed consumed per pig	Feed consumed per 100 lbs. gain
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Cornmeal........	653.5	1074.5	421	1.002	2336.5	5.56	554.9
Cornmeal, 8;.... Tankage, 1.....	657	1363.5	706.5	1.682	2784 5	6.62	394.1
Cornmeal 4;.... Soybean meal, 1.	520.5	1063.5	543	1.616	2163.5	6.44	398.4
6 hogs in each lot—Experiment III, lasting 56 days. December 22, '08 to February 15, '09							
Cornmeal, 8;.... Tankage, 1.....	843	1333	490	1.458	2145	6.38	437.7
Cornmeal, 4;.... Soybean meal, 1	846	1331	485	1.443	2103	6.25	433.6

*Only four hogs in lot fed corn and soybeans.

The corn, soybeans and tankage as used in this experiment were sampled and analyzed under the direction of Mr. J. W. Ames, Chemist of this Station, with the results as shown in Table V.

TABLE V: PERCENTAGE COMPOSITION OF FEEDS.

	Water	Ash	Protein	Fiber	Nitrogen-free Extract	Ether Extract
Corn...........	15.50	1.21	8.90	1.99	68.74	3.66
Soybeans......	11.84	4.86	38.62	1.91	25.56	17.21
Tankage.....	7.81	14.06	59.24	3.59	2.73	12.57

Table VI shows the average amount of the different food constituents consumed daily per pig throughout the experiment. It will be noted that the ration of corn alone contained a very small amount of ash and of protein as compared with the rations that contain either soybean meal or tankage in connection with corn.

Feeds for use in connection with corn should be relatively higher in protein and ash than is corn, so as to make up the marked deficiency of corn in these materials and thus provide for the growth of bone and muscle as well as for the formation of fat.

TABLE VI: FOOD CONSTITUENTS IN CONCENTRATES CONSUMED DAILY PER HOG.

Ration	Ash	Protein	Fiber	Nitrogen-free Extract	Ether Extract
Experiment II					
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Cornmeal....	.067	.495	.110	3.824	.203
Cornmeal, 8;..........	.071	.524	.117	4.051	.216
Tankage, 1...........	.103	.436	.026	0.200	.092
Total.....	.174	.960	.143	4.071	.308
Cornmeal, 4;..........	.062	.458	.103	3.540	.188
Soybean meal, 1.......	.062	.497	.024	.330	.222
Total.....	.124	.955	.127	3.870	.410
Experiment III.					
Cornmeal, 8;.........	.068	.505	.113	3.900	.207
Tankage, 1...........	.100	.420	.025	.019	.089
Total.................	.168	.925	.138	3.919	.296
Cornmeal, 4;..........	.060	.445	.099	3.441	.183
Soybean meal, 1.......	.061	.483	.024	.319	.215
Total.................	.121	.928	.123	3.760	.398

Table VII shows the warm dressed weights of the various lots. This information was kindly furnished by Messrs. Swift and Company who slaughtered the various lots at their Chicago house February 25. The home weights were taken February 22, some days after the close of the experiment, but while the hogs were receiving the same rations as were fed during the experiment. There is need for more evidence concerning the dressed percentages of swine fed on these rations before any definite conclusions on this point will be justified. The lighter dressed percentages of the two lots fed for 56 days is largely, if not wholly, explained by the lighter average live weight of these lots.

TABLE VII: DRESSED PERCENTAGES.

5 hogs in each lot.—Experiment II lasting 84 days. November 24, '08 to February 15, '09.

Ration	Weight at Wooster February 22	Warm dressed weight at Chicago, Feb. 25	Dressed percentages (warm)
	Lbs.	Lbs.	%
Cornmeal	1115.5	893	80.05
Cornmeal, 8 Tankage, 1	1421	1168	82.19
Cornmeal, 4* Soybean meal, 1	1109	896	80.79
6 hogs in each lot.—Experiment III lasting 56 days. December 22, '08 to February 15, '09.			
Cornmeal, 8 Tankage, 1	1419.5	1126	79.32
Cornmeal, 4 Soybean meal, 1	1417.5	1099	77.53

*Only four hogs in lot fed cornmeal and soybean meal.

Table VIII, based on the results that were secured from the lots that were fed 84 days, shows the cost of one hundred pounds of pork under market prices for corn ranging from 28 to 84 cents per bushel, with soybeans at $30 per ton and tankage at $40 per ton.

TABLE VIII. COST PER 100 POUNDS GAIN.

Experiment II lasting 84 days, November 24, '08 to February 15, '09.

Price of corn per bushel	Corn alone	Cornmeal, 8; Tankage, 1 (tankage @ $40 per ton)	Cornmeal, 4; Soybean meal, 1 (soybeans @ $30 per ton)
$.28	$2.77	$2.63	$2.79
.35	3.47	3.07	3.19
.42	4.16	3.50	3.59
.49	4.86	3.94	3.98
.56	5.55	4.38	4.38
.63	6.24	4.82	4.78
.70	6.94	5.25	5.18
.77	7.63	5.69	5.58
.84	8.32	6.13	5.98

Soybeans are not usually available for use at $30 per ton, but their cost of production would indicate that they may possibly soon be available at about this price. It will be noted that the financial advantage is not always with the same lot. With very cheap corn, it alone may be more profitable to use than the other rations. Using

the results secured from the three lots that were fed the rations indicated for 84 days as the basis of calculations, the corn and soybean ration would have produced the most costly gains with corn at 28 cents per bushel, and the cheapest gains with corn at only slightly above 56 cents per bushel. This table emphasizes again the importance of a knowledge concerning both efficiency and cost of rations; without such knowledge feeders cannot hope to secure best results from their feeding operations.

Although present prices for soybeans that are fit for seed prohibit their profitable use for feeding purposes, yet, with its high feeding value, effect as a soil improver, and an average yield under Ohio conditions of about 18 bushels (1080 pounds) per acre, it seems entirely probable that the soybean crop may come to be grown very extensively in Ohio for feed purposes. Besides the matter of feeding value, the effect of the soybean plant as a soil improver is worthy of careful consideration. For information relative to general characteristics, culture, etc., of the soybean, the reader is referred to Circular 78 of this Station.

Farm grown feeds have been found to be very efficient supplements for corn, but it is often better business practice to sell a part of the farm products and buy commercial feeds, rather than to feed a ration all of which has been grown on the farm. The example of soybeans is a case of this kind. At present prices—at least $2.00 per bushel, wholesale—soybeans could well be sold, and the proceeds used to buy such commercial feeds as would prove more profitable than soybeans to use with corn for fattening swine under present market conditions. Beans that have been cracked in threshing or that have been rendered unmarketable in any other way that does not impair their feeding value could be used very profitably in pork production.

CORN AND BLUEGRASS PASTURE COMPARED WITH CORN, SKIM MILK AND BLUE GRASS PASTURE.

Two lots of pigs, five in each lot, were fed rations as above. The results of this test are given in Table IX. Each lot received (for Lot 1) all of the corn or (for Lot 2) corn and skim milk that they would consume. The pigs were about four months old when the test began, July 6. Both lots were fed until September 22, 1906, when the pigs from Lot 2 were sold. Lot 1, fed corn and bluegrass pasture, was fed until their total gain was approximately equal to that of Lot 2. The rate of gain was more than one half greater with Lot 2 than with Lot 1.

TABLE IX: CORN AND BLUEGRASS PASTURE COMPARED WITH CORN, SKIM MILK AND BLUEGRASS PASTURE.

5 pigs in each lot—Experiment IV lasting 79 days. July 5 to September 20, '06

Grain ration	Initial weight	Final weight	Gain	Average daily gain per pig	Feed consumed	Feed consumed per 100 lbs. gain
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Corn..........................	349	780	431	1.091	1644.5	381.5
Corn and skim milk...........	384	1028	644	1.630	{ 1697.5 5647	263.5 corn 876.8 s.m.

It should be stated that in this, as in all other similar tests conducted at this Station, the hogs to which corn alone was fed ate very much more grass than did the hogs which received corn and skim milk. Besides the lower rate of gain made by Lot 1, this lot after having made practically the same total gain (640 lbs.) that Lot 2 made, would have sold on the market for 25 cents per hundredweight less. This point is often of great importance, but market conditions are so irregular that no attempt will be made here to advise feeders when to market their product. This matter must be decided by the feeder after considering the conditions which exist during each year. However, it can be said that economy and rapidity of gains seldom prevent advantageous marketing.

DRY LOT VS. PASTURE.

Experiments conducted during the summers of 1907 and 1908 give an excellent opportunity to compare dry lot feeding with feeding on pasture, when corn alone, or corn and tankage are used. These experiments are summarized in Table X. It will be noted that in both years the use of pasture added materially to the rate and economy of gain when corn alone was fed. In the 1907 test corn and tankage in dry lot produced almost as great and, so far as concentrates are concerned, economical gain as did corn, tankage and pasture. In the 1908 test, with younger, smaller pigs, quite an appreciable difference in rate and economy of gain is noted, in favor of the pasture lot, even when corn and tankage were fed. Pasture grass is usually a relatively cheap feed and should be used extensively for pork production, especially when grain feeds are high in price. Green feeds other than bluegrass may often be used to good advantage; among them are clover, alfalfa, timothy and rape. In both of the experiments summarized in Table X heavy grain rations were used.

TABLE X: DRY LOT VS. PASTURE.

5 hogs in each lot—Experiment V lasting 55 days. July 5 to August 28, '07.

Ration	Initial weight	Final weight	Gain	Average daily gain per pig	Feed consumed	Feed consumed per 100 lbs. gain
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Cornmeal on pasture..........	719.5	1103.5	384	1.396	1795	467.4
Cornmeal in dry lot............	709.5	940	230.5	.838	1370.5	594.5
Cornmeal, 6; tankage, 1, on pasture..................	699.5	1246.5	547	1.989	2084	380.9
Cornmeal, 6; tankage, 1, in dry lot......................	719	1246	527	1.916	2051.5	389.2
5 hogs in each lot—Experiment VI lasting 62 days. June 26 to August 26, '08						
Cornmeal on pasture..........	324.5	696	371.5	1.198	1279.5	344.4
Cornmeal in dry lot............	338.5	547.5	209	.674	1062.5	508.3
Cornmeal, 8; tankage, 1 on pasture.....................	329	831	502	1.619	1613	321.3
Cornmeal, 8; tankage, 1 in dry lot.....................	338.5	826.5	488	1.574	1697.5	347.8

The financial results that would have been secured under varying market conditions, using the 1908 test as the basis of calculations are shown in Table XI. It will be noted that the cheaper the corn the less the relative profit from pasturing in connection with both the corn and the corn and tankage lots. In this calculation a fixed charge—$1.00 for the corn and tankage lot and $1.50 for the corn lot —is made for pasture. The reason for this difference in charge for pasture is the fact, noted above, that the corn lot consumed noticeably more grass than did the corn and tankage lot.

From the foregoing it is seen that pasture may often be a source of very valuable feed. An extensive use of pasture should often be made in pork production, especially when grain is very high in price. In this connection attention is directed to the data presented in Table XIV, page 84, which shows the results secured from the use of light and heavy grain rations upon pasture. The amount of corn required for one hundred pounds gain is 467.4 pounds for the lot fed a heavy corn ration upon pasture and only 386.7 pounds for the lot which received a light grain ration. In this experiment the light grain ration was equal in amount to two-thirds of the heavy grain ration.

TABLE XI: FINANCIAL RESULTS UNDER VARYING MARKET CONDITIONS.
Experiment VI lasting 62 days. June 26 to August 26, '08.

Rations	Corn meal in dry lot	Corn meal on pasture	Corn meal and tankage on pasture	Corn meal and tankage in dry lot
Corn, 45 cents per bushel; tankage, $42.60 per ton				
Cost per hundred lbs. gain.....	$4.09	$ 3.17	$ 3.25	$ 3.31
Profit on gain in live weight of 5 hogs @ 5 cents per lb......	1.91	6.80	8 76	8.26
Profit on gain in live weight of 5 hogs @ 6 cents per lb......	4.00	10.51	13.78	13.14
Corn, 60 cents per bushel; tankage, $42.60 per ton.				
Cost per 100 pounds gain........	$ 5.45	$ 4.09	$ 4.02	$ 4.14
Profit on gain in live weight of 5 hogs @ 5 cents per lb......	loss .93	3.37	4.92	4.22
Profit on gain in live weight of 5 hogs @ 6 cents per lb......	1.16	7.08	9 94	9.10
Corn, 75 cents per bushel; tankage, $42.60 per ton,				
Cost per 100 pounds gain........	$ 6.81	$ 5.02	$ 4.78	$ 4.96
Profit on gain in live weight of 5 hogs @ 5 cents per lb......	loss 3.78	loss .06	1.08	.17
Profit on gain in live weight of 5 hogs @ 6 cents per lb......	loss 1.69	3.65	6.10	5.05

FEEDING ON BLUEGRASS PASTURE. CORN COMPARED WITH CORN AND TANKAGE. TWO TESTS.

In 1907 and in 1908 tests were conducted to compare corn with corn and tankage for feeding on pasture. The pasture used in these tests, as in the one just discussed, consisted of bluegrass and white clover. In 1907 the corn and tankage mixture consisted of 6 parts cornmeal to 1 part tankage, by weight; in 1908 the proportions were 8 to 1, for cornmeal and tankage, respectively. In both tests the hogs were fed all the grain they would consume. Table XII shows the results secured from these tests.

In each case the lot that received corn and tankage made greater gains than were secured from the use of corn alone. Less concentrates were required for a given gain when corn and tankage were fed than when only corn was given. Moreover, as was stated in connection with the comparison of corn with corn and skim milk on pasture, the lot fed corn alone consumed more grass than did the other lots. With corn very low in price it is possible that corn alone on pasture would produce more net profit than would corn and a supplemental feed. On this account, the feeder should know what results are to be expected from various rations so that he may apply local market conditions to these results.

TABLE XII: CORNMEAL COMPARED WITH CORNMEAL AND TANKAGE ON BLUEGRASS PASTURE.

Five hogs in each lot. Experiment VII lasting 55 days. July 5th to August 28th, 1907.

Grain ration	Initial weight	Final weight	Gain	Average daily gain per pig	Feed consumed	Feed consumed per 100 pounds gain
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Cornmeal, 6; tankage, 1...........	699 5	1246.5	547	1.989	2084	380.9
Cornmeal.........................	719.5	1103.5	384	1.396	1795	467.4
Five hogs in each lot. Experiment VIII lasting 62 days. June 26th to August 26th, 1908.						
Cornmeal, 8; tankage, 1...........	329	831	502	1.619	1613	321.3
Cornmeal.........................	324.5	696	371.5	1.198	1279.5	344.4

LIGHT VS. HEAVY GRAIN RATIONS IN DRY LOT.

Two experiments have been conducted to compare light and heavy rations, when swine are confined in dry lot. The results of these experiments are presented in table XIII. In these experiments the light ration was equal in amount to three-fourths of the heavy ration. It will be noted that no marked difference in economy of gain resulted—in fact, the amount of feed consumed for a given gain was almost exactly the same for the two different lots.

TABLE XIII: LIGHT VS. HEAVY GRAIN RATIONS IN DRY LOT.

Four hogs in each lot. Experiment IX lasting 196 days, September 19, 1907 to April 3, 1908.

	Ration	Initial weight	Final weight	Gain	Average daily gain per pig	Feed consumed		Feed consumed per 100 lbs. gain	
						Milk	Concentrates	Milk	Concentrates
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Sept. 19, 1907, to Nov. 29, 1907	Cornmeal, middlings, skim milk	190	557	367	1.277	1444	950	393.4	258.8
	Cornmeal, middlings, skim milk (¾ full feed,	183	463	280	.972	1083	712.5	386.8	254.5
Nov. 30, 1907, to April 3, 1908	Cornmeal 8; tankage 1	557	1457	900	1.785		3834		426.
	Cornmeal 8; tankage 1 (¾ full feed)..........	463	1122	659	1.307		2875.5		436.3
Five hogs in each lot. Experiment X lasting 62 days. June 26th to August 26th, 1908.									
	Cornmeal 8; tankage 1	338.5	826.5	488	1.574		1697.5		347.8
	Cornmeal 8; tankage 1 (¾ full feed)..........	327	689	362	1.167		1273		352.

The amount of gain was quite widely different—practically one-third more for the heavy-fed lot than for the light-fed lot. These results show that, so far as economy of gain is concerned, no material difference existed between light and heavy feeding as practiced in these tests. In rate of production and, therefore. in length of time required to produce a given amount of pork, a wide difference existed. There seems to be little reason for feeding less than a full ration to swine that are being fattened in dry lot.

The figures presented in the first part of Table XIII show something of the great capacity of swine for converting feed into meat. With the four head which were fed full rations it is seen that during the 198 days of the experiment they gained a total of 1267 pounds in live weight, consuming during this period 4087 pounds of cornmeal, 271 pounds of middlings, 426 pounds of tankage and 1444 pounds of skim milk.

LIGHT VS. HEAVY GRAIN RATIONS ON PASTURE.

With hogs upon pasture the proposition is very different from dry lot feeding, and it is often possible, by feeding relatively light grain rations, to induce hogs to eat a much larger amount of grass than when heavier grain rations are supplied, and thus effect a marked economy in production.

TABLE XIV: LIGHT VS. HEAVY GRAIN RATIONS ON PASTURE.

Five hogs in each lot. Experiment XI lasting 55 days. July 5th to August 28th 1907.

Grain ration	Initial weight	Final weight	Gain	Av. daily gain per pig	Grain consumed	Grain consumed per 100 lbs. gain
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Cornmeal..................	719.5	1103.5	384	1.396	1795	467.4
Cornmeal (⅔ full feed)....	675	982.5	307.5	1.118	1189.2	386.7

One experiment has been conducted at this Station to compare light and heavy grain rations for hogs on pasture. In this test two lots of pigs, five in each lot, were fed for 55 days upon a grain ration of corn alone with bluegrass and white clover pasture in abundance. The results of this experiment are given in Table XIV, and show that a marked lessening in amount of grain feed required for a pound of gain resulted from withholding a part of the grain, on account of the more extensive use made of a cheaper feed, pasture grass. It is not possible to ascertain the definite amount of grass consumed by the two lots; it was certain, however, that the lot which received the light grain ration consumed more grass than did the lot fed the heavy grain ration.

HOGS IN CATTLE FEED-LOTS.

It is generally considered by feeders that hogs in cattle feed-lots, depending very largely, or exclusively, upon the corn in the droppings from the steers will make as great gains as hogs can be expected to make. A number of tests conducted at this Station showed decided increase in rate of gain when a supplemental feed was used. Facilities for making these tests have been rather limited, on account of the small number of cattle that have been fattened here under conditions that would permit such tests. Consequently, only one supplemental feed, digester tankage, has been used.

These tests were conducted in conjunction with a steer feeding experiment, the plan of which is given below. Later experiments were conducted under similar conditions. The plan of the first test was as follows:

Four lots of steers, seven head in each lot, were fed upon two different rations—two lots upon each ration. Lots 1 and 3 received shelled corn, cottonseed meal, corn stover, mixed hay and corn silage. Lots 2 and 4 received shelled corn, cottonseed meal, corn stover and hay. The two lots last mentioned received more corn and more dry roughage than did the lots first mentioned, on account of not receiving silage, which, of course, contained both grain and roughage. All lots of cattle received the same amount of cottonseed meal daily per steer.

TABLE XV: HOGS FOLLOWING STEERS.

Three hogs in each lot. Experiment XII lasting 63 days, March 20* to May 21, 1907.

Lot	Steer ration	Hog ration	Initial weight	Final weight	Total gain	Average daily gain per pig
			Lbs.	Lbs.	Lbs.	Lbs.
1	Silage	Grain from droppings and one-third pound tankage daily per hog in addition	290	565	275	1.46
3	Silage	Grain from droppings	280	434	154	.81
4	Dry	Grain from droppings	305	530	225	1.19
6	Dry	Grain from droppings and one-third pound tankage daily per hog in addition	331	655	324	1.71

Four hogs in each lot. Experiment XIII lasting 56 days, May 22 to July 16, 1907, inclusive.

Lot	Steer ration	Hog ration	Initial weight	Final weight	Total gain	Average daily gain per pig
1	Silage	Grain from droppings and one-third pound tankage daily per hog in addition	445	766	321	1.43
3	Silage	Grain from droppings	460	657	197	.88
4	Dry	Grain from droppings	470	692	222	.99
6	Dry	Grain from droppings and one-third pound tankage daily per hog in addition	445	755	310	1.38

Total gains of lots fed tankage .... 1230 pounds.
Total gains of lots not fed tankage .... 798 pounds.
Increased gains by lots fed tankage .... 432 pounds.

* Weight of hogs taken March 20th; feeding of tankage began March 21st.

During the first part of the experiment three hogs were put with each lot of seven cattle; later these hogs were replaced by a thinner lot and four hogs were placed with each lot. The first set of hogs was under experiment for 63 days, the second lot for 56 days.

No corn was fed to the hogs, and, as the cattle feed racks were so constructed as to prevent the grain being thrown out, the hogs secured no grain except that which appeared in the droppings from the steers. All lots were kept supplied with a mixture of ashes and salt. It is of interest to note that the lots fed tankage cared less for the ashes and salt than did the other lots. The tankage was fed at the rate of one-third of a pound daily per pig, in the form of a thin slop. It may be very conveniently fed in this manner and was greatly relished by the hogs, in fact, they exhibited an almost ravenous appetite for it.

Table XV shows the results secured from experiments during which the corn in the steers' droppings was the only grain to which the hogs had access. It will be observed that greatly increased gains resulted from the use of the supplemental feed. There was no way of measuring the exact cost of gains with the different lots, as the amount of corn that passed through the steers might have varied materially. However, there is abundant evidence to show that the use of tankage was very profitable. The two lots that were fed tankage ate 295.5 pounds of this material and made 432 pounds greater gains than did the two lots which were subjected to similar treatment with the exception of the use of tankage. All of the lots left a small amount of corn in the manure, and it cannot be said for a certainty that the tankage fed lots did not eat more corn than did the others.

TABLE XVI: HOGS FOLLOWING STEERS.

Five hogs in each lot. Experiment XIV lasting 71 days. Jan. 15, to March 25, 1908.

Steer ration	Hog ration	Corn fed	Tankage fed	Initial weight	Final weight	Gain	Av. daily gain per pig.
		Lbs	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Silage	Grain from droppings, corn and tankage	962.5	121.15	548	1030	482	1.357
Dry	Grain from droppings, corn and tankage	662.5	121.15	553	1000	447	1.259
Silage	Grain from droppings and corn..........	916.5		537	875	338	.952
Dry	Grain from droppings and corn.........	659.3		547	*755	348	1.017

Total gain of lots fed tankage.. 929 pounds
Total gain of lots not fed tankage.. 686 pounds
Increased gains by lots fed tankage.. 243 pounds

*One hog taken out March 14, weight 140 pounds.

In tests conducted later than the ones reported above, dry shelled corn was fed in addition to that which was present in the steers' droppings. Tables XVI and XVII show the results of these tests, which are in close agreement with the ones previously discussed. In the tests summarized in Table XVII, tankage was used, but in different amounts, one-half of the lots receiving one-third of a pound of tankage daily per pig, the other half receiving twice as much.

TABLE XVII: COMPARISON OF DIFFERENT AMOUNTS OF TANKAGE FOR HOGS FOLLOWING STEERS.

Five hogs in each lot. Experiment XV lasting 70 days. January 14th to March 24th, 1909.

Steer ration	Initial weight	Final weight	Gain	Av. daily gain per pig	* Corn consumed during experiment	Tankage consumed during experiment
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Silage	517	960	443	1.265	619	175
Dry	530	1040	510	1.457	415	175
Silage	543	1110	567	1.620	650	262.5
Dry	567	1210	643	1.837	549	262.5
Six hogs in each lot. Experiment XVI lasting 70 days. March 25th to June 2nd, 1909.						
Silage	625	1107	482	1.147	433	213
Dry	620	1099	479	1.140	293	213
Silage	625	1163	538	1.280	433	319.5
Dry	625	1103	478	1.138	293	319.5
Six hogs in each lot. Experiment XVII lasting 69 days. March 26th to June 3rd, 1908						
Silage	595	1200	605	1.461	896	274
Dry	590	1155	565	1.364	723	274
Silage	590	1045	455	1.099	873	137
Dry	†470	‡720	375	1.179	671.5	105.2

Total gains of heavy fed tankage lots .... 1170 pounds.
Total gains of light fed tankage lots .... 830 pounds.
Increased gains by heavy fed tankage lots .... 340 pounds.

* Besides that secured from droppings of steers. † Only five hogs to begin with.
‡ One hog taken out May 7th, weight 125 pounds.

These three experiments conducted to secure data in regard to the amount of tankage which should be fed to hogs in cattle feed lots for best results have shown greater gains, on the whole, from two-thirds of a pound of tankage daily per pig than from only one-third of a pound daily. It will be observed that two of the three tests show better results from the use of the larger amount of tankage. It is expected that further work along this line will be done in connection with future cattle feeding experiments. If other supplemental feeds, suitable for use with corn are more readily available for use than tankage, there is no reason why they should not be used. As has been suggested before, the feed that will produce the desired results at the least cost should be used; to decide this point, market conditions will need to be carefully considered.

SUMMARY.

Corn alone, at prices approximating those that now prevail, is not a profitable ration to use in pork production.

Feeds richer in protein and mineral consitituents should be supplied to supplement corn in a way to provide for the growth of muscle and bone as well as for the production of fat.

The use of supplemental feeds of the character mentioned in the preceding paragraph has given good results for feeding in ordinary dry lots, in cattle feed-lots and on pasture.

Skim milk, soybeans, tankage, middlings and pasture grass all proved valuable feeds for use in connection with corn. The supple mental feed to use will depend very largely upon market prices.

In the comparison of light and heavy grain rations for dry lot feeding no marked advantage of either was evident so far as economy of gains was concerned. As would be expected, the heavy grain ration produced more rapid gains than did the light grain rations.

Marked economy in cost of gains resulted from the use of a light grain ration in place of a heavy grain ration for swine on pasture. If a cheaper feed may be used in place of the grain, it is often possible to lessen very materially the cost of pork production by feeding a light grain ration. If concentrates are to be used exclusively, the use of a heavy grain ration would be advisable, unless the aim of the feeder is to hold the stock in a low or moderate condition in order to secure cheaper feeds for fattening later.

It is important for feeders to understand market conditions as well as efficiency of feeds. The rations that produce the most rapid gains are not necessarily the most profitable feeds to use. On the other hand, rations that produce cheap gains may produce these gains so slowly that the profits will be very small.

Either home grown or commercial supplemental feeds may be used in connection with corn to good advantage, and feeders should be ready to use whichever will be most profitable. It will often pay to exchange farm grown feeds for commercial feeds. On the other hand, it is often true that the use of feeds grown on the farm will prove more profitable than the use of commercial feeds.

Feeds other than those discussed in this bulletin have given good results when used to supplement corn. Buttermilk, meat meal, linseed oilmeal, clover, alfalfa and various other feeds may often be fed with corn to good advantage. Whatever feeds are used in pork production, the feeder should pay close attention to market prices of the various feeds that may be had, and use the most economical, efficient feeds that are available.

THE BLADE BLIGHT OF OATS
A BACTERIAL DISEASE

OHIO

Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., OCTOBER, 1909.

BULLETIN 210

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The Bulletins of this Station are issued at irregular intervals. They are paged consecutively and an index is included with the Annual Report, which constitutes the final number of each yearly volume.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 210. OCTOBER, 1909.

THE BLADE BLIGHT OF OATS—A BACTERIAL DISEASE.

By THOS. F. MANNS.

INTRODUCTION.

During the past three seasons the oat crop of Ohio has sustained much loss from a blight disease which has been quite general throughout the Central and Eastern states. From the many inquiries by the farmers of Ohio, and the great differences of opinion among scientific workers, it is quite evident that the nature of the trouble has not been well understood. Many of the farmers supposed the trouble to be of the nature of a rust (See page 98). Among the scientific workers the conclusions reached were widely different. In one section insects[1] were noted as a cause; in another case,[2] while the origin of the trouble was held to be in doubt, its wide spead development was believed to be due the cold, wet, cloudy season. A third investigator found the disease not to be directly the result of insect work[3]. Prof. J. Dearness[4] writing through the Farmer's Advocate, a Canadian paper, in 1907, (after having reviewed the New York State Reports for 1889-1890 by C. H. Peck) supposed the cause to be either bacterial, in the class with the bacterium of pear blight, or else due to the reduction of the vitality of the oats through climatic causes. Prof. Selby, in a report on plant diseases,[5] supposed the trouble to be due to the great changes of weather, possibly aided by aphides. A similar trouble in 1890 was pronounced by the Division of Plant Pathology, Department of Agriculture, Washington, D. C., to be due to bacteria[6]. In Connecticut a similar disease was supposed to be

[1]Special Bulletin No. 38, Michigan Agricultural College, July 1907, R. H. Pettit.
[2]Press Bulletin No. 286, Ohio Experiment Station, July 15th, 1907, Chas. E. Thorne.
[3]Journal of Economic Entomology, June 1908, pp. 190 and 191, H. A. Gossard.
[4]Farmer's Advocate, London, Ontario, Vol. XLII, No. 775, Aug. 1, 1907, Prof. J. Dearness.
[5]Ohio Agricultural Report, 1907, p. 891.
[6]Journal of Mycology, Vol. 6, pp. 72-3, 1890, B. T. Galloway and E. A. Southworth.

due to insects[7]. What appears to have been the same disease was prevalent in New York in 1889 and was pronounced by C. H. Peck[8] as due to a fungus; however, this view was later modified and Prof. Peck pronounced the disease not to be due to fungi, and he further noted that he believed it was not the results of insects or nematode work[9]. In 1906 the Connecticut Station reported an outbreak of a disease somewhat similar to the blight in which they could find no bacteria as an associated cause. "The trouble apparently resulted from unfavorable weather conditions, possibly aggravated by some root disease."[10] Insects many times in the past[11 12 13] have been assigned as causing blights of oats which appear very similar from descriptions to the severe blight of 1907-8.

CAUSE.

The author finds the disease, as manifested in Ohio, to be caused by a symbiotic relation of two species of bacteria; the disease being greatly influenced by weather conditions and to some extent disseminated by insects.

PREVIOUS LITERATURE ON THIS DISEASE

Very little has been previously written upon this disease, and where studies or notes have been reported the articles are very short; for these reasons the writer quotes very fully from the references noted. The disease as it appeared in 1890 was described by Galloway and Southworth as follows:[6]

"During the months of May and June, 1890, we received repeated complaints and inquiries concerning a mysterious oat disease which then threatened to destroy the entire crop of the Eastern and Central States.

During the month of May, when the oats were from 6 inches to a foot in height, the leaves suddenly began to turn brown and die at the tops. The lower leaves were attacked first and the brown color soon extended their entire length. In a very short time all the leaves were dead or partially brown, and the prospects were that the plants would die and the oat crop be a total failure. About the middle of June, however, the fields began to revive, the oats put out some few fresh, green leaves, most of them headed out, and by the first of July many of the fields appeared in a fair condition on superficial observation. In reality, however, the losses from the disease will amount to from 35 to 75 percent of the crop, according to the locality. Very discouraging losses are reported from the State of Pennsylvania, where there is probably not a healthy oat field to be found. Kentucky and Tennessee have suffered even more, their present averages as reported to the Statistical Division being the lowest ever reported from any state for a staple crop.

[7]13th Annual Report of Connecticut Agricultural Experiment Station, 1889, p. 180. Roland Thaxter.

[8]New York State Report, 1889.

[9]New York State Report, 1890.

[10]Report of the Connecticut Agricultural Experiment Station for the year 1906, Part V., p. 316.

[11]Insect Life, Vol. III, p. 306.

[12]Bulletin 108, Division of Entomology, Agric. Exp't. Sta., Minn., April 1908, F. L. Washburn.

[13]Bulletin 44, United States Department of Agriculture, Division of Entomology, 1904.

[6]Journal of Mycology, Vol. 6, p. 72-3, 1890.

The disease extends from New England to Georgia, and from the Atlantic coast as far west as Indiana and Illinois. It is not present in Michigan. All the agents for the Statistical Division agree in ascribing the cause of this remarkable decline in the oat crop to the same thing, namely, a "blight" or "rust" which struck the fields in May.

The disease prevented the oats from stooling well, and it frequently happened that all the shoots but the main one of a stool were killed. As a result the oats are very thin, and in riding along by a field even at a considerable distance one can see to the ground between the drill rows when the oats are in full head. Besides this the losses are augmented by the fact that the amount of green foliage which developed after the attack, was not sufficient to produce a strong growth of the surviving stalks, nor to supply material for a good-sized head; the straw is therefore short and light and the heads small. The heads do not seem to be well filled, and threshing will probably reveal a lighter yield than farmers themselves expect.

Such a universal disease can be attributed to no deterioration of soil or lack of cultivation, although there is no doubt that good cultivation will produce better oats than poor, even when they are diseased. The disease has attacked oats on the best as well as on the poorest soils, fields that were fertilized as well as those that were not. The oats are best, however, in level well cultivated and drained fields, while they are poorest in low, wet spots and on hillsides and other places where the soil is thin. In such places they are too short to be harvested.

A very careful study of the plants has been made in the field and laboratory, but nothing in the way of a fungous or animal parasite that could cause the trouble has been found. From the nature of the disease our attention has been directed mainly to a study of it from a bacterial standpoint. Bacteria have been found in every specimen examined. Nearly 200 cultures have been made in at least a dozen different media and all have yielded two germs, one of which is exceedingly abundant. In nearly 50 cases the disease has been produced in young pot-grown plants by inoculating from direct material. Inoculations of young plants with pure cultures are now under way and it is hoped that some definite results will soon be obtained from this source.

(Since writing this the disease has been produced in fifty or more cases by inoculating with the more abundant organism. Five days after inoculating, the characteristic discolorations appeared and cultures made from these have yielded the typical organism in a nearly pure condition.)"

There is still a possibility that although the disease may be caused by bacteria they are dependent upon certain conditions of the atmosphere for their development, and need not be feared another year. Experiments to settle this question are also under way.

What appears to have been the same disease was described by Prof. C. H. Peck as occurring in New York in 1889 and the cause was attributed to a fungus, *Fusicladium destruens*. He reported as follows:[8]

"In the southern part of St. Lawrence County, which was visited by the writer the past summer (1889) scarcely a field of oats was free from this disease. So prevalent was it that the general color of the fields was changed thereby, and it was the opinion of the owners that their oats were rusting badly. Upon close examination, no rust was to be found. In its stead, the discoloration of the leaves and the fungus now described appeared. It is apparently a very injurious and destructive fungus."

[8]New York State Report 1889, C. H. Peck.

However, in 1890, Dr. Peck found upon further study of the disease, reason to modify his former conclusions in regard to Fusicladium being the cause. He reported as follows:[9]

"When my last report was written, this fungus (*Fusicladium destruens*) was suspected of being the cause of the disease, which has appeared over a wide extent of country, and in the fields examined scarcely an unaffected plant could be found. It is hardly possible that the Fusicladium could have spread so extensively in so short a time. It is more reasonable to suppose that it, like the other fungi mentioned, is a consequence rather than a cause of the disease." He noted, however, that the injury appeared not to be the work of insects or nematodes.

The Connecticut Station recognized the blight and reported as follows[7]:

"**Coleothrips 3-fasciata Fitch:** A 'rust' of oats has been the cause of much complaint throughout the State during the past summer, and where examined proved to be due, in most cases, not to the common fungus rusts (*Puccinia coronata and P. graminis*); but to a minute insect which Mr. Pergande, of Washington, has kindly determined as probably Coleothrips 3-fasciata Fitch. Fields infested by it have a reddish, wilted look and often mature comparatively little of their seed. No remedy can be suggested in this case."

Miss Freda Detmers, botanist of the Ohio Experiment Station for 1890 and '91, mentions a blight of oats due to bacteria upon which she did some work, quoted as follows:[14]

"The work of the division during the past year has mainly been confined to a careful study of the fungous diseases of plants. * * * * Briefly stated the diseases investigated are as follows:" Among many others is mentioned "an undescribed bacterial disease of oats."

Pettit described the trouble in March 1907 as follows[1]:

"From all parts of the state, complaints are coming in with respect to the condition of the oat crop. The last week has seen a notable change in the outlook. The young oats in a large part of the state have suddenly become as if stricken by blight, the outer leaves turning yellow and afterwards reddish until, after a little time, the field appears as if badly rusted. A closer examination shows that there are few if any rust pustules and the appearance on the surface is just enough different from that produced by rust to raise a doubt as to the real cause of the difficulty.

Careful examination with the aid of a powerful lens shows the culprit to be a minute insect called a thrips, very small, and very quick in its movements, jumping like a flea when disturbed and disappearing completely. These little creatures have narrow wings with fringes of long hairs instead of the ordinary form of wings. They scrape the surfaces of the oat leaves and cause them to become withered and to turn yellow and die. Now, this little creature has never been seen in numbers by the writer and it is very difficult to judge just what will be the outcome of the infestation. If one might judge by the behavior of its relatives one would expect the condition to improve after one or two good rains, since thrips, in general, thrive in hot, dry weather, and do not do well when it is moist. However, it seems to be quite serious in places where there has been a fairly good supply of rain. The larger the plants are, the better they fare.

[9]New York State Report, 1890.

[7]13th Annual Report Connecticut Agricultural Experiment Station, 1889, p. 180, Dr. Roland Thaxter.

[14]Ohio Experiment Station, in the Annual Report for 1891, p. XXXIV.

[1]Michigan Agricultural College, July 1907, Special Bulletin No. 38.

Now, there seems to be nothing one can do to check the trouble at this time. If it were possible to stimulate the growth of the plants in any way it would be a benefit, but such a course seems to be impossible. All plant life seems to be more susceptible to insects when plants are in poor condition for any reason, and the backward, cold, wet spring furnishes a very sufficient reason for the lack of vigor and resisting power which they should have to help repel the invaders."

Director Thorne, of the Ohio Station, reviews the disease[2] in a press bulletin as follows:

"Reports received by the Ohio Experiment Station indicate a general prevalence over the state of an abnormal condition of oats, shown by many of the blades turning yellow, or reddish yellow, in spots or streaks, and finally dying at the tips or throughout the entire length.

A similar condition was manifested by the oat crop of Ohio and farther west in 1890, followed by a considerable reduction in yield and such a condition is reported by the Connecticut Experiment Station as occuring in that state in 1906.

The attack of 1890 was pronounced by the Division of Vegetable Pathology, U. S. Department of Agriculture, to be due to bacterial infection. The Connecticut Station failed to find evidence of such infection last year, and we have not yet found conclusive evidence of such infection in the present attack.

In the case of the present attack plant lice have been mentioned by many observers as being unusually abundant on oats, but we have not as yet found conclusive evidence as to whether they have or have not, borne an important part in the spread of the trouble. We know of no remedy or prevention.

In all cases similar weather conditions have been observed, namely: excess of cold, rainy weather, followed by hot sunshine, and it appears that these conditions have been the chief factors in producing the outbreak.

In this connection the following extract from the report of this Station for 1890 (it being then located at Columbus) may be of interest:

'The Spring of 1890 was very unfavorable to farming operations throughout the greater portion of Ohio, on account of almost incessant rains. The planting of corn, oats and potatoes was generally delayed, and cultivation was much interferred with until after the middle of June. On the Station farm oats and potatoes were planted late, and both crops suffered so much from blight that not half an average yield was obtained.'"

Prof. H. A. Gossard in reviewing the insect troubles of 1907 writes as follows:[3]

"During the spring, wheat and oats over Ohio suffered from a peculiar disease, marked by a reddening, yellowing and browning of the leaves, and a general stunting of the growth and retardation of the development in all respects. From the fact that the grain louse, *Macrosiphum granaria*, was noticed in considerable numbers in some fields, the newspapers and many correspondents attributed the damage to the lice. Others suspected thrips of causing the mischief. After an examination which I deemed adequate, I concluded that neither of these insects was primarily responsible for the disease so far as Ohio was concerned, though both species added to the trouble to a

[2]Press Bulletin No. 286, Ohio Experiment Station, 1907.
[3]In the Journal of Economic Entomology "Notes of the Season" June 1908, pp. 190-191.

considerable degree in some fields. The majority of the diseased plants, however, were damaged but little by either insect, and many of them not at all, so far as I could determine. Corn, clover, alfalfa, strawberries and many weeds suffered in precisely the same way, as inferred from their external symptoms, and no insects whatever could be found upon them. I decided the trouble was probably wholly physiological in character, and was in all likelihood caused by the cold, wet spring. Parasites overtook the lice in most localities before they became excessively plentiful."

Prof. Selby in reviewing plant diseases in his report for 1907 says:[5]

"Oats showed a frightful collapse by leaf-blight when the season turned brighter; it seems to have been due to the sudden stress of the change (of weather), possibly aided at times by lice or aphides."

The same disease was evidently quite prevalent in Ontario in 1907. Prof. J. Dearness writing through the Farmer's Advocate[4] in answer to subscribers to that paper, after reviewing Dr. Peck's reports for New York, 1889-90, writes:

"I have examined the specimens of oats received from you, and labelled, respectively, from a correspondent in the county of Oxford; Mr. Twedle, county of Wentworth; Mr. Brodie, Middlesex; and from several other farms in the county of Middlesex.

The disease on all the specimens has similar characteristics. It appears as a blighting of the outer end of the leaf (but not usually of every leaf of the plant) and spreads along the veins towards the stem. As the tissues die, the color changes to a yellowish or reddish brown. I find no mark in root, joint, stem or leaf of the invariable presence of any insect. If the affection were due solely to adverse conditions of soil or weather, all the leaves, as well as the other parts of the plant, might be expected to be similarly discolored."

"His description (referring to Peck's N. Y. State reports) of the affected oat fields agrees exactly with those of your correspondents. The fungus he most strongly suspected at first is present on most of the leaves received here. If it is not the cause, but only a concomitant of the disease, then I should say that we have here either a destructive bacterium to be put in the class with the bacterium of pear blight, or a case of the reduction of the vitality of the oats, by some climatic cause, to such an extent as to permit the invasion of the fungi observed. The problem is an interesting and important one. It may already have been attacked and settled so far as the bacteriologist is concerned. If so, I have not heard the result."

Writing later he says:

"Since reporting to you on the specimens of blighted oat-leaves I have had the opportunity of visiting a number of fields. It may be said of all these that, in general, the stems, youngest leaves and panicles are not attacked by the blight.

In all the grass plants the regions of most vigorous growth are at the joints or just above them, while tissues at the leaf-tips, particularly of the older leaves, have the least vigor. The disease was limited to the latter regions of the oat plant.

I am of the opinion that the blight made no progress after a favorable condition of the weather set in, and that the changes in the color of the leaves and the invasion by fungi occurred and continued in areas of the leaves where the protoplasm had already lost its usefulness to the plant."

[5]Ohio Agricultural Report, 1907, p. 891.

[4]Farmer's Advocate, London, Ont., Vol. XLII, No. 775, Aug. 1, 1907.

The disease was noted in Canada in 1907 as follows:[15]

"Blighting of Oats: In addition to the above there was a rather wide-spread physiological blight reported during the summer. The trouble was mostly in oat fields and specimens showed the upper parts of the plants as yellowing and dying. Investigation failed to disclose any causative fungi present. The trouble was very probably due to unfavorable weather conditions, the root system having been impaired by a continued cold spell following an earlier warm season, the plants were unable to get proper nourishment and water supply from the ground."

What appears to have been an outbreak of a somewhat similar disease, though apparently not identical, has been described by G. P. Clinton[16] as follows:

"This trouble was first seen at Portland, the second week in June. During June and July it was noticed in almost all the oat fields examined, and so much have considerably reduced the yield. The leaves, especially the lower, became a sickly yellow, and many finally died prematurely. In some respects this trouble resembled the bacterial disease that occasionally occurs in the early summer in the oat fields of the West; but the leaves lacked the water-soaked appearance of that disease, and on examination failed to show any bacteria present. The trouble apparently resulted from unfavorable weather conditions, possibly aggravated by some root disease, though the few examinations made of the roots failed to show any suspicious fungus at work there. June and July had many heavy rain storms suddenly followed by bright hot days, and these sudden changes, as in other cases already mentioned, probably caused the injury. The same trouble was seen to a less degree on a number of other grasses, both wild and cultivated."

EXTRACTS FROM LETTERS—1907.

The large number of inquiries to Farm Journals and letters to the Experiment Station from farmers characterize the disease and emphasize its severity. The following extracts are typical:

"Fayetteville, Brown County, Ohio, 6-9-'07

Dear Sir:

There is something the matter with the oat crop here this season of which you can see by sample No. 2 sent you in this mail.

It looks very much as though some fields are gone entirely now. My oats were the earliest sown in this immediate vicinity and were the last to be attacked by this trouble, that is, a part of the field is turning red very rapidly. There are many of the green bug (aphis) in my field and I was wondering if they are the cause of all this. I am sending blades, both top and bottom and in all stages of color from beginning to end. What is wrong?

BERNARD QUINN."

"Ashtabula, Ashtabula County, Ohio, 6-14-'07.

Dear Sir:

I have been looking over my oats this afternoon and find they are looking much better. Enclosed please find sample of oats.

In travelling around this part of the country, I find the most of the oats are damaged similar to mine. The damage is all on the high ground.

C. J. METCALF."

[15]Report of the Ontario Agricultural College and Experimental Farm, Dept. of Botany, p. 49, 1907.
[16]Connecticut Agricultural Experiment Station Report 1906, Part V, pp. 316-17.

"Camden, Preble County, Ohio, 6-27-'07.

Dear Sirs:

I am sending under separate cover specimens of oats which I wish you would kindly examine. The oats in this entire country are affected with some disease which causes the leaves to turn brown beginning at the tips. Would you please let me know the nature of the trouble and what we may expect of this land if it is sowed in wheat the coming fall?

D. W. McQueen,"

"LeRoy, Medina County, Ohio, 7-8-'07.

Dear Sir:

Will you please tell us the cause of the universal turning red and dying of the leaves on the oats, and what the probable result is going to be?

H. J. Freeman."

"Fredericktown, Ohio, 7-3-'07.

Gentlemen:

The oats through this county (Knox) is turning a reddish color of the blades, and seems to be dying.

I examined the roots and could distinguish nothing on the roots that I thought was an insect, excepting on one root.

C. F. Braddock."

EXTRACTS FROM LETTERS 1908-9.

"Ansonia, Darke County, Ohio, 3-7-'09

Dear Sir:

I would like for you to send me a receipt for a dip to dip oats; when my oats get about six inches high it commences to get rusty, and don't grow thrifty, and when it heads it only about half fills the oats. It is all affected the same in this country.

F. J. Folkerth."

"Ansonia, Ohio, 3-23-'09.

Dear Sir:

What is it that is in the oats; is it a smut or does it come from the cold weather? The fields of oats get red as fire, that is, the blades. Is there anything that I could do for it?

R. D. Fields."

"Wainwright, Tuscarawas County, Ohio, 3-8-'09.

Dear Sir:

My oats are badly infested and yielded poorly the last two years.

Geo. Schmitz."

"Camden, Preble County, Ohio, 2-28-'09.

Dear Sir:

Would you kindly inform us as to the advisability of spraying or rather treating seed oats for blade blight?

We were badly infected with this two years since in Preble county.

Dr. D. W. McQueen."

"Ashland, Ashland County, Ohio, 3-4-'09.

Dear Sir.

Kindly send me formula for treating rust in oats.

Palmer & Donley."

"Leipsic, Putnam County, Ohio, 12-28-'08.

Dear Sir:

We had exactly the same disease on our 1908 crop as we did on our 1907 crop, and I am thoroughly convinced if we had not ideal weather for oats crop, we would not have gotten scarcely anything.

I have given the subject very close attention for the last two years and I am thoroughly convinced that it is some disease on the oats and not climatic or weather conditions.

G. O. CRUIKSHANK."

"Fostoria, Seneca County, Ohio, 2-1-'09.

Dear Sir:

Will you please give me directions for treating seed oats that are affected with rust or what ever it is that has caused the oats to turn red before heading out? Oats in this vicinity have not yielded more than half a crop in the last two years, owing, as most farmers believe, to this trouble, although the last season was an exceptionally good one.

J. L. CRUIKSHANK."

"Shelby, Richland County, Ohio, 12-28-'08.

Dear Sir:

Will you please send me instructions how to treat oats for sowing to prevent blight?

R. C. WINBIGLER."

"Polk, Ashland County, Ohio, 1-11-'09.

Dear Sir:

Can the Station give me any information in regard to the condition of the oat crop of last year, which may be beneficial this year?

W. M. FELGER."

The following quotations, taken from the correspondence of Prof. A. D. Selby, Botanist and J. M. Van Hook, Assistant Botanist, in answer to queries in 1907, show many observations which throw much light on the oat blight disease.

"Wooster, Ohio, 6-18-'07.

Mr. C. J. Metcalf,
Ashtabula, Ohio.

Dear Sir:

This form of oat blighting has been quite common at the Station this year, especially on certain varieties, but is largely disappearing with better weather. It does not seem to be due to either insect or fungus, but to conditions surrounding the plant.

J. M. VAN HOOK."

"Wooster, Ohio, 6-28-'07.

Daniel C. Mayne,
Miamisburg, Montgomery County, O.

Dear Sir:

We have the same trouble with oats on the Station farm and have received specimens from many parts of the state. We believe this due to weather and resulting soil conditions more than anything else. There is more of it than I have ever seen before and many varieties on the plots here will be badly damaged even if it lets up at once. With the advent of continued warmer weather, I look for the trouble to diminish, though it made the disease worse at first. However, the green bug or louse, is appearing in numbers in many places and may do much damage unless we have clear warm weather.

J. M. VAN HOOK."

"Wooster, Ohio, 6-29-'07.

Mr. E. W. Falcott,
Kent, Portage County, O.

Dear Sir:

Your oat trouble is a general complaint this year. There were trace of it last year, but nothing like the present. On our variety plots it is ver severe. Some varieties are worse than others and worse on high ground, a you say is true in your case. The yellowing of leaves up to this time, at least seems largely due to bad weather, dark and cold. Increased by the sudde hot weather of the last two weeks.

J. M. Van Hook."

"Wooster, Ohio, 6-29-'07.

Mr. R. S. Sharks,
Ada, Hardin County, O.

Dear Sir:

This seems to be due not to any parasite but to bad conditions of weather Evidently it has been aggravated very much by the recent change to hot, sun shiny weather, though such a change will doubtless be for the best as soo as the plants become adjusted to these conditions. In many cases the crop i considerably damaged already.

The green bug or plant louse is appearing and is damaging oats quite good deal, but here on the Station farm parasites are developing rapidly an killing these bugs. Bright weather will do much to stop bug injury.

J. M. Van Hook."

"Wooster, Ohio, 7-2-'07.

Mr. W. M. Cook,
Canton, Stark County, O.

Dear Sir:

Your oats are attacked by aphides (lice) upon the leaves which punctur them and then these leaves subsequently turn red.

A. D. Selby."

"Wooster, Ohio, 7-8-'07.

Mr. H. W. White,
Shiloh, Richland County, O.

Dear Sir:

At the beginning of the oat trouble there was a very great abundance so called green bugs or aphides and the surface of the leaves appeared to hav numerous punctures from them. Later with the finer weather the parasite killed off a large number of the lice, but there are still an abundance of leave to break down, which in part lacks explanation. Latterly, however, the ne leaves formed are all right and the shortage in the crop from the attack wi probably not be excessive.

A. D. Selby."

"Wooster, Ohio, 7-12-'07.

F. S. Aten,
Nevada, Wyandot County, O.

My Dear Sir:

This leaf blight has been under study here for some time. I first ob served it about three weeks ago and associated with it then were very larg numbers of plant lice (greenbugs). When the fine weather came on the para

sites killed off the plant lice and since then the leaves have kept dying in most localities without our being able to explain just why this kept up. Possibly the lice attacks had something to do in the beginning, and the turning to hot weather some more. We do not expect an ordinary oat crop and especially with the later sorts. Early sorts ought to make 3-4 of a crop here but the later sorts little more than 1-2 crop, I fear.

A. D. SELBY."

"Wooster, O., 7-22, 1907.

Mr. F. P. Stump,
Convoy, Van Wert Co., Ohio.
My dear Mr. Stump:

You have doubtless seen the press bulletin issued by the Station with respect to this leaf blight of oats. In the beginning some four weeks ago the crop of aphides (green bugs) was so great as to be held responsible. Later on the leaves continued to blight even after the parasites had killed off the plant lice. Possibly for physiological reasons, the leaves continued to break down.

A. D. SELBY."

"Wooster, O., 7-22, 1907.

Mr. C. P. Oferholtzer,
Hoytsville, Wood Co., Ohio.
Dear Sir:

The head of oats which you send shows what we call "blast" and this serious blast is no doubt due in part to the leaf blight that has been prevailing.

A. D. SELBY."

The severity and nature of the disease is quite readily understood from the above quotations. Though worded differently and emphasized from different standpoints, yet it is quite conclusive that the same general type of trouble was evident in all cases, except possibly the one reported from Connecticut in 1906. The writer finds that the disease differs greatly in its field aspects. Only under the most favorable weather for the spread and developement of the disease, does the trouble assume such pronounced and severe characteristics as were manifested through the central and eastern states in the season of 1907. Under weather conditions more conducive to the growth of oats, and less suitable for the aggressive action of the parasites, the appearance of the trouble becomes entirely changed; leaves which were but partially infected and which under trying conditions would have turned brown in less than a week, under favorable conditions take on a light, yellowish color and may even assume later a natural green. Extensive observations were made upon the disease in the field and under control conditions in the greenhouse, and it is evident that the disease manifests its presence by changes in color varying from a light yellowing, which apparently checks but little the growth of the oats, to a pronounced reddening, which in severe cases kills the blades, leaving only the younger leaves and the central axis alive.

COMMENTS UPON THE ABOVE EXTRACTS.

In a review of previous literature upon this oat blight it is apparent that in only one instance has definite infection work been carried on to determine the cause of the disease, in which case Galloway and Southworth find two bacteria; one of which, they report, produces the blight when inoculated into the oats. This work as reported in the above citation covered but one phase in the study of the disease, and apparently required verification before it could be accepted. A fuller and more extensive report is desired from these workers, covering the several phases of this disease, in order that the organisms may be limited and the nature of the disease more fully understood.

G. P. Clinton, in the 1906 Report of the Connecticut Station, stated that he found no bacteria associated with the yellowing of oats as prevalent that season. From his report it would appear that probably only microscopic examination was made. If such was the case and no cultures were run, it could yet have been a bacterial disease, and the organisms easily missed. On the other hand, cultures would quickly show whether bacteria were present or not. He doubts whether the disease is identical with the bacterial disease noted in the western oat districts.

From a careful study of Pettit's work and notes in Michigan in 1907, (Bul. 251, Mich., March, 1908) it appears rather clear to the writer that the oats in that state were subject that season to both the thrips injury and the bacterial blight. His careful description of the field manifestations, and his illustration, Fig. 3, p. 114, are very typical of the bacterial blight. His illustrations, Figs. 4 and 5, on the other hand are very typical of insect work. It is possible that the thrips were a means in the distribution of the bacterial blight.

In reviewing the literature on the 1890 outbreak of oat blight, we find Galloway and Southworth note: "The disease (ascribed to bacteria) extends from New England to Georgia, and from the Atlantic Coast as far west as Indiana and Illinois. It is not present in Michigan." In notes upon the same year (1890), F. L. Washburn, writing in Bul. 108, p. 264, Minn. Experiment Station April, 1908, on the work of *Toxoptera graminum* says: "In 1890 it was found in injurious numbers on wheat in Indiana and in certain sections of that state the oat crop was a failure through its ravages." It is even possible that the diseased condition of oats in Indiana as noted by the two different writers above for 1890, was due to the same causes, and resulted from the combined work of aphides and bacteria.

The description of the field conditions, given by the others quoted, are all apparently very similar to those given by Galloway and Southworth; and although the causes assigned are, in general, entirely at variance, the writer believes the disease in each instance is the same, and due to bacteria as isolated by the authors noted above; however, instead of assigning the cause to *one* of the organisms, the writer finds the disease to result from a mutual relationship of the two organisms. That this conclusion is correct appears evident from experiments carried on the past two seasons, (see p. 107 and following).

THE BLIGHT DISEASE NOT RESTRICTED TO OATS.

Among the observations made by others in the past upon the blight disease, there are several in which are noted somewhat similar troubles upon wheat[3], grasses[10], alfalfa[3] and other crops[2 3 10]. The writer has carried out much preliminary culture work on the several different kinds of plants which have shown yellowing or blight symptoms, and although this work has not been supported by extensive inoculations as with the oats, the evidence is sufficient to show that the disease may and does affect some of the more susceptible varieties of other plants.

During March, April and May of 1909 inoculations were made in the pathologium on wheat (Gypsy and Poole) and corn, on three different occasions, covering periods of different atmospheric conditions. In no instance did either of these varieties of wheat show signs of infection; however, with the corn, during a cloudy, moist period, several of the lesions spread quite rapidly, from which at a distance of twelve inches from the point of inoculation, by means of plate cultures, the organisms of the disease were separated.

During the present growing season (1909) careful observations have been made on all the varieties of wheat, oats, barley and other crops grown at the Station, for the appearance of this disease. On one variety of wheat, known as Extra Square Head, recently brought here for trial, the blight at a period favorable for its development showed quite extensively. Cultures readily showed the specific organisms to be present. Among the other wheat varieties not a trace of the disease could be found.

There are on wheat and other plants several different fungi, which in their preliminary attack bring about a yellowing that could, off hand, easily be classed with the bacterial blight of oats. Mildew and rust on both wheat and oats may cause yellowing in moist, cloudy weather, which when followed by hot, clear, droughty weather, will cause the blades to turn quite red.

The leaf-spot of alfalfa when severe may cause yellowing. The same is true in leaves of other plants affected with fungous troubles.

As is noted elsewhere, among the oat varieties considerable difference is seen in resistance to this disease.

Among the barleys grown at the Station, one variety, known as Primus, showed a susceptibility to the disease even more marked than did the Wideawake variety among the oats. The Oderbrucker variety of barley also showed an occasional blade infected. These observations were verified by cultures.

What appears to be the same disease has been observed on the blue grasses and timothy; in these cases, however, instead of the blades yellowing, the disease appears restricted to the culm, at heading time, causing, just above the upper joint, a limited lesion which kills the upper part of the stem and causes the head to dry up or blight. This type of injury, off hand, appears similar to insect work, but examination by stripping down the sheath, fails to show that insects are present, or signs of boring; cultures and micro-examinations reveal blight bacteria as the cause. These observations have not been followed up by inoculation work. Infection just above the upper joint would appear to be a matter of spattering by rain above the sheath, and running down between the sheath and stem rather than infection from below, passing upward through the vascular system.

During the growing seasons of 1908 and 1909 considerable culture work was done upon yellowing alfalfa, especially upon those plants showing much yellowing and little leaf-spot (*Pseudopeziza medicaginis*). In many instances the presence of bacteria, in the stem and upper leaves, sometimes in large numbers, showed conditions entirely abnormal. The significance of these conditions requires much further investigation. The writer is of the opinion, that alfalfa, on many of our soils, has to contend with certain bacteria which are somewhat specific in their attack upon the plant. Whether these bacteria are the same as those which cause oat blight or not, has not been worked out; however, upon preliminary plating they are very similar.

As noted elsewhere (p. 122) it is probable that thebacterial flora has much to do with the health and growth of certain crops. In this respect alfalfa may be much more exacting than many of our other crops. Experiments carried out in the pathological garden in 1908 and 1909, in soil above the average in fertility, on which were planted red clover, alsike and alfalfa, showed that the red and alsike clovers produced an excellent growth, while the alfalfa was very weak and yellow. Leaf-spot was present on the alfalfa, but not to such an

extent as to account for the weak, yellow growth. An examination of the root systems showed the red clover and alsike to be abundantly supplied with nodules, while the alfalfa had none on many plants and very few on any. Plate cultures made from leaves and stems of the alfalfa showed many internal bacteria, while the red and alsike clovers showed no such abnormal condition. From such evidence it seems probable that either certain specific organisms, or the bacterial flora and its by-products, were not favorable to alfalfa.

DISTRIBUTION OF THE BACTERIAL BLIGHT OF OATS.

From the literature quoted it is very apparent that the disease is of wide distribution. Depending on seasonal conditions the disease manifests itself from the Canadian lake provinces on the north, to the gulf states on the south, and from the New England and middle Atlantic states on the east, to Illinois and states south thereof, on the west. The writer is of the opinion that not a season passes but the disease shows itself in at least a limited way in some locality of the area included above. It requires but ten days to two weeks of favorable weather to bring about preliminary infection. The amount of this infection apparently depends upon the height of oats, the amount of spattering, association of insects, and the continuance of cloudy, humid weather.

AMOUNT OF LOSSES OCCASIONED BY THE BACTERIAL BLIGHT OF OATS.

It is very difficult to estimate the exact amount of loss occasioned by an outbreak of fungous or insect trouble, owing to the fact that several factors are always at work. The plant pathologist is inclined to emphasize the destructive work of fungous and bacterial diseases, while on the other hand the entomologist chiefly sees the work of the insect. If we are to draw our conclusions from a general summary of previous literature on oat blight we can readily see that the losses have been very large at times. The seasons of 1890 and 1907 as well as 1908, were the ones in which the oat blight was by far the most general and destructive. A comparison of the yields in Ohio for these seasons, with the average yield for the past 18 years, shows a shortage respectively of 36.7, 24.3 and 14.4 percent, or stated in bushels per acre, for the above three seasons the yield was respectively 19.8, 23.7 and 26.8 bushels as compared with an average of 31.3 bushels per acre for the past 18 years. (See Table II, showing acreage, yield, etc., from 1890 to 1908 inclusive).

The literature quoted clearly points out the losses as indicated by field conditions. That these losses in some localities have been very much in excess of those in others is evident from the observations noted in the correspondence (See letters, pp. 97 to 101).

Several of the writers indicated the prevalence of the disease with much loss for three seasons consecutively. Such prevalence of the disease means that these certain localities have been subject to an excess of rainfall, cloudiness, etc., furthered by the soil becoming filled with the organisms responsible for the disease.

TABLE I: Showing oat acreage, yield and seasonal conditions in Ohio from 1890 to 1908 inclusive.

Year	Acreage	Bushels produced	Yield per acre	General condition of growing season
*1890	959,012	19,049,033	19.8	Season very late, seeding much delayed through excess rains, oats late, badly blighted.
1891	879,463	26,515,935	30.1	(Failed to obtain data.)
1892	827,823	22,541,473	27.2	Very wet and unfavorable for seeding. July very droughty.
1893	856,235	24,537,989	28.6	April and May very wet; June and July droughty, oats short.
1894	1,051,773	31,991,896	30.4	Season as a whole very favorable, with good promise.
1895	1,095,142	34,013,739	31.06	May favorable for acreage. June and July condition generally low.
1896	1,262,805	36,027,464	28.5	Very favorable season for large acreage. Growing season good. Large oat crop is the prospect.
1897	1,052,605	30,563,033	29.	May very wet, oat seeding generally delayed. Acreage small. June and July conditions fair.
1898	976,902	30,694,432	31.4	May not favorable for large acreage. Much injury in June on low grounds from heavy rains.
1899	969,565	33,296,912	34.3	Oat seeding rather late. Drought through June and July, plants short, but filling well.
1900	1,251,248	43,193,577	34.5	May favorable for large acreage, but rather dry for good growth. July very favorable.
1901	1,053,876	33,936,143	32.1	Seeding late, but June quite favorable, though heavy rains. July favorable.
1902	1,188,947	46,789,843	39.3	May favorable for acreage and growth; June conditions fair; July fair except on low ground, injury from rains.
1903	1,213,228	37,305,993	30.7	May favorable for large acreage, but quite dry. June conditions good. July conditions good. Some red rust.
1904	1,467,052	58,312,740	39.7	May very favorable for seeding. June favorable. July favorable.
1905	1,449,112	49,731,954	34.3	May very wet; June conditions fair. July oats doing nicely.
1906	1,343,247	44,179,782	32.9	May, heavy rains, seeding retarded. June, dry and not favorable for growth. July, oats doing poorly, though slightly better than June.
19 7	1,429,792	33,906,233	23.7	Spring very wet, season late, cold, cloudy, oats generally blighted.
1908	1,281,805	34,363,980	26.8	May unfavorable for seeding. June conditions favorable. July droughty, condition not good.

Average yield of oats for eighteen years, (1890 to 1907) 31.3 bushels per acre.
* From the Ohio Statistics, Report of the Secretaries of Agriculture.
NOTE: The bad blight years for oats, viz., 1890 and 1907 show respectively a reduction in yield of 36.7 percent and 24.3 percent from the average for the past 18 years.

THE OAT BLIGHT CAUSED BY TWO SPECIES OF BACTERIA IN SYMBIOTIC RELATION.

At the present day it is well known that relationships among organisms greatly retard or increase their virulence, and also the possibility of disease production. Dr. W. E. Musgrave[14] emphasizes the importance of symbiosis existing among organisms pathogenic to animals. In reviewing this work[15] W. A. Hooker, in the Experiment Station Record, writes as follows:

"The influence of symbiosis upon the pathogenicity of micro-organisms: Bacterial and animal symbiosis are discussed at length by the author. Many of the phenomena not now understood in the etiology and pathology of disease are said to be due to symbiotic combinations between the micro-organisms. Variability in the virulence of bacteria is one of the most marked features and the reason for this variability is but partially understood. The author concluded that, 'the most promising field for laboratory research in the future will be the study of cause and effect, in the complex relation and interaction of micro-organisms with each other and in their environment of complex symbiosis and the ever changing and multiple conditions found in hosts.'"

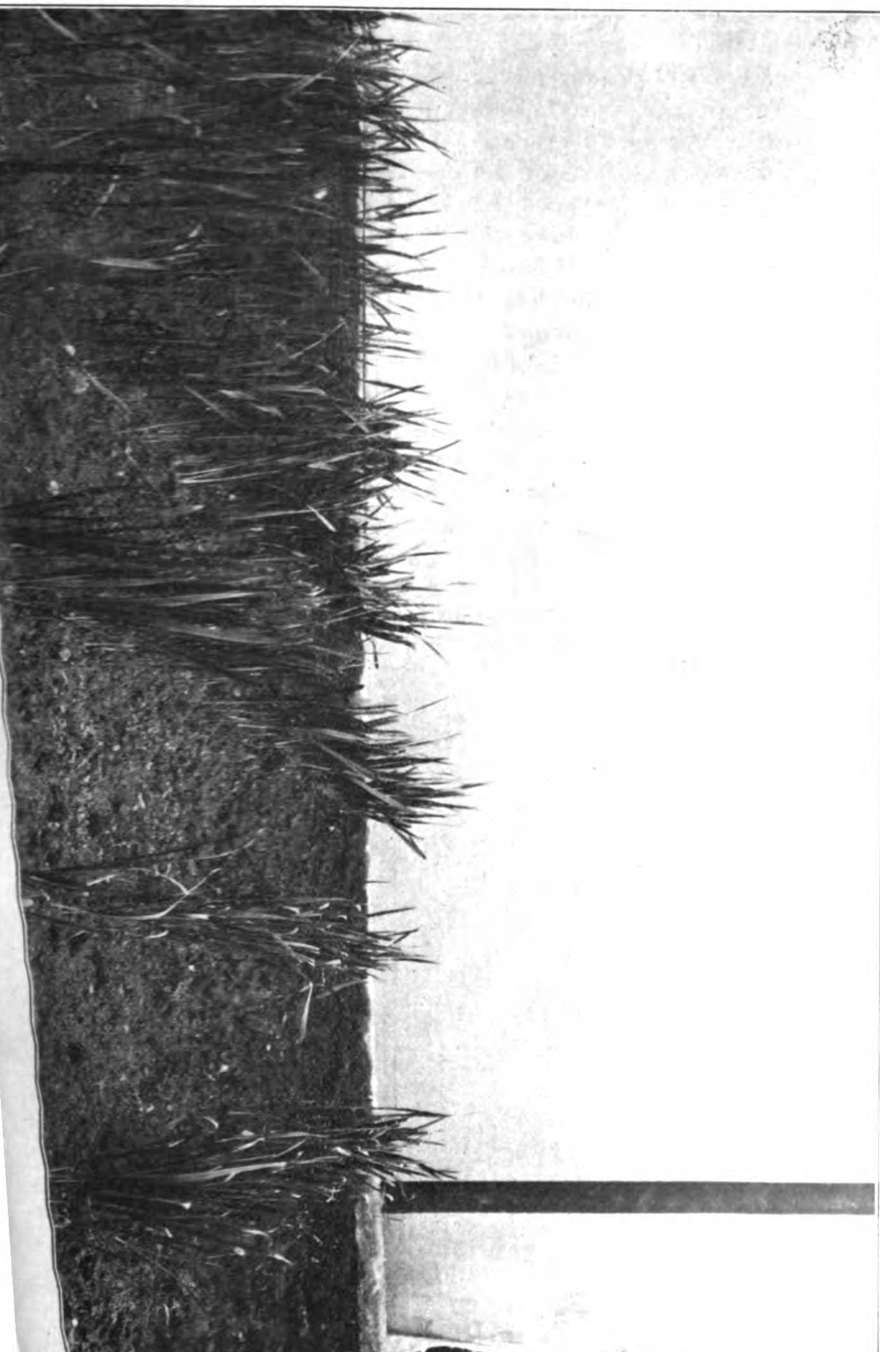
The experiments carried out with the oat blight organisms clearly substantiate the statements made by Dr. Musgrave. Not alone is the production of disease apparently very dependent upon the symbiosis of these two organisms, but it is found also that the virulence and viability of the white organism (*Psuedomonas avenae* n. sp.) upon artificial culture media, depend greatly upon the association with the yellow organism (*Bacillus avenae* n. sp.) in mixture. The extent of this interrelation as exhibited in disease production is clearly shown in the illustration, Plate I, in which the two rows at the right were infected with a mixture of the two organisms, while the fourth and fifth rows from the right were infected respectively with the yellow and the white organism separately. Where the mixture was applied the blight resulted in twelve days, but where the organisms were infected separately no typical blight resulted. The yellow organism produced no lesions at all and the white organism produced but limited and non-typical lesions. In carrying cultures through the winter the writer had several series of cultures from different sources in which in some instances the organisms were carried through separately, while in other instances the organisms were carried over as mixtures. In renewing these cultures, at the end of a period of nearly nine months, it was found that the white organism, where carried over in pure culture, in several cases failed to grow, but in every instance where it was carried over in mixture with the yellow organism the viability and virulence of the former organism were more marked than when carried over separately.

[14] Philippine Jour. of Sci., B., Med. Sci. 3 (1908), No. 2, pp. 77-88.
[15] Experiment Station Record, Vol. XX, No. 8, p. 788, 1909.

DESCRIPTION OF PLATE I.

Showing, in the two rows at the right, results of the infection with a mixture of artificial cultures of the yellow and white bacteria (*Pseudomonas avenae* n. sp. and *Bacillus avenae* n. sp.) of the brown blight of oats, inoculated by means of a hypodermic needle, twelve days prior to the time of photographing. The blades in the infected row at the right were inoculated in the leaves about one inch from the tips. In the infected row, second from the right, the plants were inoculated near the base of the leaves and also through the stems; the infection in this row greatly retarded the growth of the plants and several even succumbed to the disease. (See Plate II showing the condition of this row as compared with the check, photographed two weeks later). The row at the left of the infected (three rows from the right) is a check row in which the leaves were pricked with control punctures from which no injury or blight lesion resulted. The fourth row from the right was inoculated with the yellow organism, (*Bacillus avenae* n. sp.) from which no lesions resulted; the fifth row from the right was inoculated with the white organism (*Pseudomonas avenae* n. sp.) and the results were, lesions formed slowly, extending about one-half to one inch from the point of infection, then remained checked. The evidence of the symbiotic relationship existing between the organisms which produce the blade blight of oats is clearly brought out in this experiment. By one eighth.

3-11-09. Original.



The influence of mutualism upon the virulence and activity in disease production became much more noticeable when cultures of the white and yellow organisms, which had been carried over separately in pure cultures, were mixed and attempts were made to infect the oat plants, in which case the infection was very slow and required more than a week's difference in time before the lesions became active and typical, as compared with those inoculations from cultures carried over as mixtures. In the latter case the infection was noticeably active from the time of inoculation, clearly showing that the relationship of the yellow organism with the white assisted in some way in keeping up the virulence of the latter. As stated above, the white organism (*Pseudomonas avenae* n. sp.) when inoculated alone into the oat plant produced limited lesions, which were much lighter in color than those produced when a mixture of the organisms was used. In practically all cases of separation of organisms from diseased oats these two bacteria were found more or less abundant, thus again tending to show that the disease is a result of a symbiotic relation between these organisms.

OTHER OBSERVATIONS WHICH POINT TO BACTERIA AS THE CAUSE.

The outbreak of the blight on the Ohio Experiment Station grounds at Wooster, in 1908, caused very little loss, though at one time it was quite threatening. During that season the aphides were more or less associated in the spreading of the infection. One incident pointed very clearly to the probability of the trouble being bacterial. The Agronomy Department carried out a clipping experiment on oats to learn if stand and yield could be bettered. At the time of this clipping the blight was quite conspicuous. The work of the sickle in cutting through the infected leaves was a means of generally spreading the blight throughout the plots. In less than two weeks each of the clipped plots showed a very marked contrast in the amount of disease as compared with the plots which had not been clipped.

Further evidence was gathered the present season (1909) when the blight made its appearance with no insect complications. The disease in the majority of infected leaves began as small yellow spots on different parts of the blades. When these points of infection were numerous the infected areas quickly became confluent, and the collapsed leaf showed a brownish, mottled appearance. Occasionally infection was observed which began on the sheath near the midrib, resulting in a light, yellow streak extending clear to the end of the blade. This streak later turned brown (see Plate XIII).

THE POSSIBILITY OF OAT BLIGHT FROM OTHER CAUSES.

Insect relations: In a review of literature bearing upon the oat blight suggestions are found, that point to other factors that may be important in causing blight diseases of oats. Prominent among these causes are mentioned insects, for examples, such as *Macrosiphum granaria*, *Syphocoryne avenae*, *Toxoptera graminum*, *Anaphothrips striatus*, *Coleothrips tri-fasciata* (*Thrips trifasciata*) and others. The writer would find it somewhat out of his line to experiment with each of these organisms as to the type of injury they would produce on oats. However, in order to obtain data on the relationship of the grain aphides found prevalent upon oats in this vicinity during the seasons of 1907, 1908 and 1909, the writer carried out a number of experiments, all of which show that these grain lice are not the primary cause of the blade blight of oats. Further, that the type of injury produced by them is very characteristic and easily recognized from the bacterial blight. While the blight disease was prevalent in 1908 (June) the writer gathered a number of oat aphides feeding on blight infected plants. These insects were caged with young oats that showed no sign of the blight disease. Ten to twelve days after the caging the blight began to show, while the check outside the cage remained free. It was observed that, on several of the leaves most thickly covered with aphides, no yellowing was apparent. Plate cultures of the yellowing leaves showed the blight bacteria plentiful, while cultures from those blades on which were many insects, but which showed no yellowing, gave, on the contrary, no blight organisms. This pointed to the probability that the aphides were simply means in distributing the disease. Cultures were then made of live aphides to learn whether the bacteria were surviving internally (see lower ill. Plate V). It was evident that the bacteria were present in abundance within the insects and likewise very viable. Inoculations into oats with a mixture of these bacteria, taken from aphides, produced infection resulting in the typical brown blight.

In order to further investigate the relationship of aphides to this bacterial blight, more extensive experiments were planned and carried out during the months from January to June 1909. Oat aphides apparently free, that is, not carrrying the bacterial blight, were confined in a cage on oats, from the time when the oats were two weeks old until they were two and one-half months old. The oats at the age of four weeks were literally covered with the aphides of two different species. (See Plates III and IV and their descriptions). The type of injury caused by these insects came on very slowly and differed greatly from the bacterial blight, infections of which were running simultaneously. (compare Plate IV with Plate X).

DESCRIPTION OF PLATE II.

Showing the effects of the blade (bacterial) blight of oats upon plants five weeks old. The row at the right was inoculated when the plants were one week old (only two leaves out) through the sheath and leaves by means of a hypodermic needle with a mixture of artificial cultures of the yellow and white bacteria (*Pseudomonas avenae* n. sp. and *Bacillus avenae* n. sp.) of oat blight. Ten days after the inoculations the leaves showed the typical preliminary yellowing of the brown blight. Check punctures were made in the control row at the left with no resulting lesions. Twelve days after the row was inoculated, both rows were caged in and grain aphides, two species which were free from, that is, not carrying the bacterial disease, were placed on the sick row to learn in what time the blight would be transferred by these insects to the control row: in two weeks the infections were quite general, being carried by the aphides from the sick row to the check row. This experiment clearly shows the relationship of grain lice to the bacterial blight of oats. By one-sixth.

3-26-09. Original.

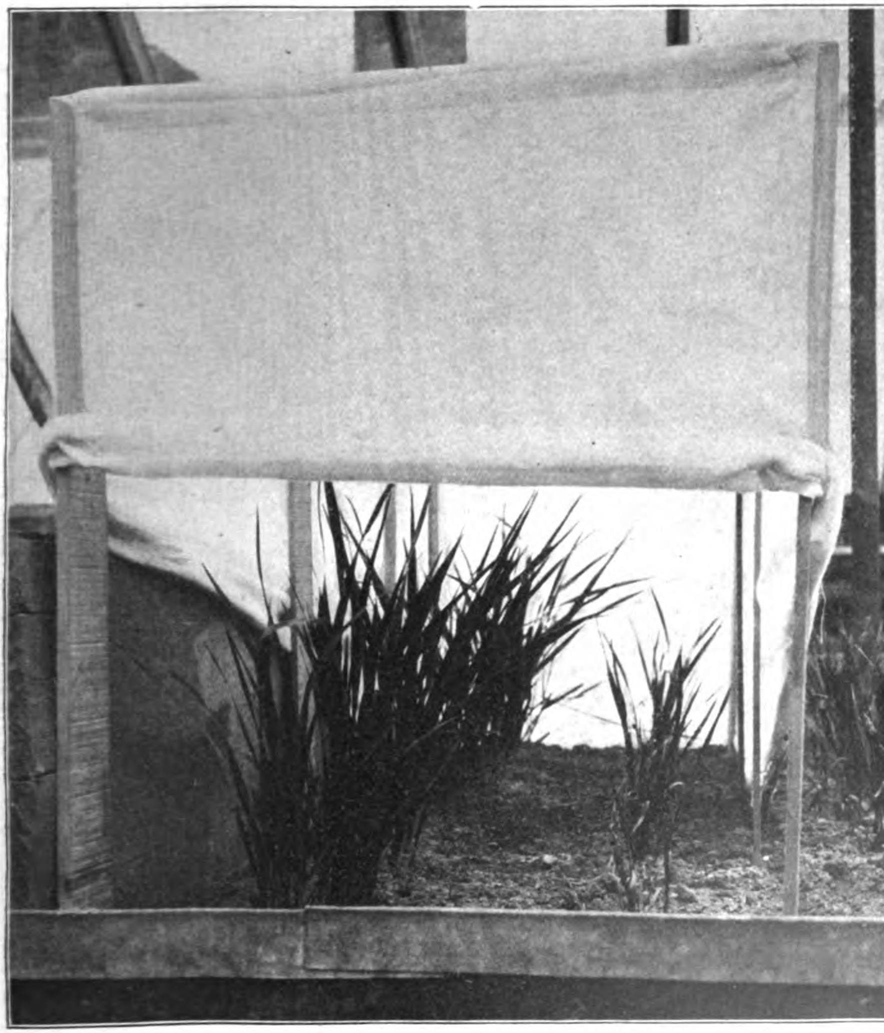


PLATE II.

DESCRIPTION OF PLATE III.

Showing cage containing oats on which two species of grain aphides worked for 2 1-2 months until the oats were literally covered, without producing the blade blight. (See illustrations in Plate IV.) The insects were apparently free from the bacteria which cause the blade blight of oats. The result of the work of aphides on oats differs entirely from the bacterial blight (compare Plate IV, Fig. 3, showing aphis work, with Plate X showing bacterial blight). At the time the above photograph was taken the aphides had been at work seven weeks and literally covered the oats. This experiment clearly shows that grain lice are not the primary cause of the oat blight. By one-sixth.

3-26-09. Original.

Further, to demonstrate the relation aphides bear to the spread of the disease, an experiment was carried out as follows: Oats well along with the bacterial infection were covered with aphides and caged in, along with a check (healthy) or non-inoculated row, to learn whether it were possible for the insects to carry the disease from the sick plants to the healthy plants, and if so, in what time. This experiment demonstrated that aphides were carriers of the disease, and the time required for visible infection was practically the same as from inoculation by hand, viz., seven to fourteen days; (see Plate II and description). This again verified the conclusions reached in 1908, and showed that aphides are only a secondary factor in the spread of the blade blight.

The direct result of aphis-sucking on oats may be called a blight, but of a nature entirely different from the bacterial blight.

EXPERIMENTS TO DETERMINE THE NATURAL MEANS OF INFECTION.

The general prevalence of the disease would suggest the probability of a trouble surviving in the soil. If such were the case, one would suspect infection to take place through one of two methods, viz., by penetration of the roots, followed by a traversing of the vascular system, finally working its evil effects throughout the leaves, or by rains spattering the disease upon the leaves and the infection taking place through the stomata. Experiments were run to learn whether either of these methods would bring about infection. Following the first method, virulent, artificial cultures of a mixture of both organisms were poured directly upon the root system, the latter being partially uncovered. No infection took place, though the atmospheric conditions maintained were the most favorable. Seed thoroughly soaked in mixed cultures of the organisms previous to planting failed upon growing, to show any blight.

Following the second method the writer took similar cultures and sprayed upon the blades. Infection followed within twelve days, identically of the same type as observed in fields, thus showing that stomatic infection is possible, and probably the chief way; the disease being spattered on by rains. These experiments were carried out in the pathologium in March and April, 1909. In 1908 similar spraying infections were carried out, with this difference, that one series of leaves were slightly bruised previous to spraying. The results were that the leaves previously bruised took the infection much more readily than did the unbruised, though the disease was present on both. This would suggest that heavy, beating rains which cause light bruises on the foliage might be a means of bringing on active infection.

Secondary infection by insects proved a further means in the distribution of the disease, as noted elsewhere. It was thought possible that the disease might be related to the apple blight and that probably aphides were carrying it back and forth, as it has been noted that *Macrosiphum granaria* and *Syphocoryne avenae*[13] pass part of their existence on the apple. The writer gathered twigs of apple affected with blight and numerous twigs covered with aphis eggs, and bred the insects from the latter in cages containing oats. In two series of experiments along these lines, the insects on hatching failed to transfer themselves to the oats, though several generations were produced on the sprouting apple twigs. These experiments would seem to indicate that the eggs found so prevalent on the apple in 1908-09 were not those of *Macrosiphum granaria* or *Syphocoryne avenae*, but probably *Aphis mali*. (See Figs. 1-2-3, Plate XV). Cultures made of the apple and pear blight organism showed it to be entirely different from the white organism, *Ps. avenae* n. sp., of oat blight.

THE BLIGHT OF OATS IN ITS RELATION TO ATMOSPHERIC CONDITIONS.

The disease in its relation to weather conditions is very similar to that of the late blight of potatoes[18], and the blight of pear and apple. The former is known to be a disease prevalent during those seasons when much rain, cloudiness, and wet, muggy weather prevail. Every plant disease may be said to have its certain favorable meteorological conditions. Whetzel[19], writing on the bacterial canker of apple, states:

> "It is well known that the "blight" in the twigs of pear and apple trees is more active and severe during a continued period of warm, muggy weather. The same is to be said of the cankers on the limbs and bodies of the trees. It was repeatedly noticed during the past season that the active spread of the cankers was coincident with certain periods of rainy weather. The progress of the disease through the bark is always abruptly checked on the appearance of bright, sunny days. The recurrence of favorable weather may often cause a renewal of activity, the canker spreading and increasing its former extent."

From observations of field conditions and control experiments in the pathologium, the writer is convinced that the chief factors in the spread and production of the blight disease of oats are rains, excess of humidity and cloudiness. Excess of these conditions reduces the vitality of the oat plant and leaves it undoubtedly much more susceptible to the disease. Primary infection is chiefly stomatic, resulting from the spattering of the organisms upon the blades by the rain. Following such means of infection it would be

[18] A. D. Selby, Ohio Naturalist, Vol. VII, No. 4, pp. 79-85, 1907.

[19] The Blight Canker of Apple Trees by H. H. Whetzel, February, 1906, Bulletin 236, Cornell University Experiment Station.

logical to expect the most rapid spread of the disease during periods of rainy, cloudy weather. Control experiments, in which the air was kept nearly saturated and plants well watered, readily showed that these were the conditions most favorable for the aggressive growth and spread of the disease. Under such conditions the amount of infection following inoculation was nearly 100 percent. On the other hand, under experiments in which the air was kept dry, the plants sub-watered, and in which the sun was bright, the disease was quickly checked and the plants quite readily outgrew the injury. The percent of infection following inoculation under such conditions was very small.

The writer, in carrying out experiments under Prof. Bolley, of the North Dakota Experiment Station[20], in the study of the ascension of sap in tree medication, observed that, on days of much sunshine and little moisture in the atmosphere, the ascension of sap and the capability of the tree to feed were excessive, as compared with those days when the atmosphere was nearly saturated and the sky heavily hung with clouds. In the latter case it was observed that often the tree, instead of being capable of feeding, actually had an outward or back pressure which could be compared to the spring flow of sap during sugar harvest. It is believed by the writer that this stagnation of the sap within plants during moist, cloudy weather offers to certain specific organisms a medium very suitable for their growth, while on the other hand, the plant under such conditions is prohibited from producing protective enzymes which are more or less capable of destroying or preventing the invasion of bacterial parasites. A cold or cool atmosphere, other conditions being practically equal, is more favorable for the spread of the bacterial lesions, than is a warm atmosphere. This was clearly proved by experiments running simultaneously under cool and warm conditions in the pathologium during February and March, 1909. These experiments were duplicated with similar results. In the cool room, which was directly connected with the warm apartment (the temperature in the latter being maintained by artificial heat) the lesions spread with much more rapidity than those in the plants under warm conditions. This would appear to be the prevailing condition in 1907 (see Table II, p. 121).

In the case of the oat blight, should the disease reach the stage in which the leaves are generally yellowed, and following which, the weather suddenly changes from a cloudy, moist condition to that of bright sunshine with quick drying, the extent of the injury becomes greatly aggravated. The majority of infected leaves quickly take on a brown color and entirely collapse.

[20] Fourteenth Annual Report of the N. Dak. Agric. Exp't. Sta. for 1903 pp. 55-58.

The data summarized in Table II, pp. 119-121, show the meteorological conditions for the years 1890 to 1909 inclusive. By a glance at this table, the season of 1907 (the year of general oat blight), is to be noted as very abnormal throughout the growing period in April, May, June and July. The temperature for these months ranged respectively 7.2, 6.8, 4.0 and 1.3 degrees below the average normal. The general cloudiness was very excessive. These two factors, together with the prevailing wet spring, were ideal for the activity of the bacterial blight. That low temperature is not the chief factor in blight production is evident when we compare the growing season of 1890 with that of 1907, in which former year the blight was much more severe. The temperature variations in 1890 for the months of April, May, June and July were +1.5, —1.4, +3.8 and —6.2 respectively, from the normal. The month of June, the time when the greatest blight distribution and injury take place, shows a high average temperature.

TABLE II: Showing the variations in mean temperature and rainfall in Ohio for the months of April, May, June and July from 1890 to 1909 inclusive. Also number of cloudy and partly cloudy and rainy days for the same period.

	1890				1891			
	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + traces	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + traces
April	+1.5	+ .68	18.5 8.8	*12+2	+2	—0.57	18 9	*12+3
May	—1.4	+1.25	23. 10.9	17+2	—1	—1.84	19 10	11+2
June	+3.8	+ .65	18.8 14.2	15	+2	+0.85	17 12	15+1
July	—0.2	—1.38	13.2 10.3	7+2	—4	+0.41	15 10	11+1
	1892				**1893**			
April	—1	+0.56	22 11	14+3	+0.6	+3.29	25 10	18+3
May	—1	+2.09	25 11	17+2	—1.3	+0.37	25 11	12+3
June	+3	+1.42	21 13	19+3	+0.7	—0.74	21 15	14+1
July	N	+0.37	16 12	10+3	+1.6	—0.88	16 13	9

* Data in these columns taken at Wooster, Wayne County, O. The other data is the average rom all other weather stations of the state.

† See bottom, p. 121.

TABLE II: Continued.

	1894				1895			
	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + Traces	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + Traces
April	+0.6	−0.71	19 8	*12+4	+1.6	−0.85	19 11	*10+1
May	+0.4	−0.55	23 12	18+3	+1.3	−4.34	18 11	8+4
June	+1.2	−1.33	15 12	8+4	+1.7	−1.40	15 10	3
July	+1.3	−1.66	14 12	6+2	−1.2	−1.12	24 14	7+2
	1896				**1897**			
April	+6.3	−0.16	20 10	11+3	−1.2	+0.30	11 10	12+3
May	+7.5	−1.55	19 13	15+3	−3.9	+0.05	20 12	11+2
June	−0.7	+0.87	20 15	17+2	−2.0	−0.97	17 13	7+4
July	+0.3	+4.63	11 12		+2.4	+1.09	19 14	12+3
	1898				**1899**			
April	−3.0	−0.60	18 9	9+4	+2.2	−1.58	21 12	11+5
May	+1.	+0.12	21 11	14+3	+2.4	+0.69	28 17	14+4
June	+1.5	−0.90	13 10	6+4	+1.2	−0.56	12 8	11+6
July	+2.8	+0.40	16 12	9+7	+0.2	+0.22	18 12	13+2
	1900				**1901**			
April	+0.5	−1.01	16 8	8+3	−3.8	+0.48	20 5	14+3
May	+1.9	−1.07	18 11	8+3	−1.8	+0.38	21 11	16+4
June	−0.5	−0.42	18 11	12+4	+0.7	+0.87	18 13	17+2
July	+0 4	+0.73	16 12	9+3	+4.4	−1.25	12 10	4+3
	1902				**1903**			
April	−2.2	−0.68	20 9	10+5	0.0	+1.26	19 7	13+4
May	+1.7	−0.48	17 11	7+4	−2.4	−0.72	14 9	8+3
June	−3 3	+3.95	19 12	14+6	−5.3	+0.11	21 11	13+4
July	+0.2	+0.78	15 11	12+1	−0.9	−0.08	15 12	7+2

* See bottom, p. 119. † See bottom, p. 121.

TABLE II: Concluded.

	1904				1905			
	Temp. variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total + Traces	Temp variation from †normal	Precipitation variation from †normal	Cloudy days Total Partial	Rainy days Total Trace
April	−5 4	+0.66	22 8	*15+4	−1.4	+0 35	19 8	*10+5
May	−0.5	+0.16	19 9	14+5	−0 6	+2.06	19 10	15+2
June	−1.6	−1.06	17 10	10+5	−1.9	+0·75	17 9	11+3
July	−2 6	+0.22	16 11	10+4	−0.8	+0.09	19 12	12+4
	1906				1907			
April	+2.3	−0.96	16 8	8+3	−7 2	−0.01	22 7	14+3
May	+0.1	−1.46	18 10	9+2	−6.8	−0.20	20 10	12+3
June	+0.1	−0.53	18 12	8+5	−4.0	+0.81	17 9	15+2
July	−1.8	+1.17	17 11	15+2	−1.3	+1.40	18 13	15+4
	1908				1909			
April	+1.4	+0.82	18 7	13+3	−0.4	+1.3	21 11	12+3
May	+1.4	+1.22	22 12	15+6	−2.4	+1.1	19 10	12+3
June	−0.1	−1.32	13 10	10+3	+0.8	+1.9	20 12	17+0
July	+0.1	−0.02	16 11	13+4				

* See bottom, p. 119.

† 1908 Normals:

	Temp.	Rainfall
April	49.6	2.87
May	61.4	3.60
June	69.3	3.84
July	73.8	4.1

RELATION OF SOIL AND FERTILITY TO THE OAT BLIGHT.

As noted in the literature quoted (see pp. 92, 93) it is quite apparent that the type of soil and the condition of its fertility have little restraint upon checking the distribution of the disease; by this it is not intended to convey the idea that well-drained and fertilized fields do not, under blight conditions, yield more and withstand the evil effects of the disease better than do poorly drained and run-down soils. The facts are that the disease is prevalent in well drained and rich soils as well as on poor and ill-drained soils; but the density of growth of the plants on the better soils tends to prevent spattering; vigorous plants resist the rapid spread of the lesions when infection does take place, and finally recover more quickly from the disease, than plants of lower vitality on weak

and poorly drained soil. Observations would seem to point to the conclusion that the bacteria which cause oat blight are probably more or less persistent soil organisms. If such is the case, it again emphasizes the need of a much greater knowledge of the bacterial flora existing within the soil, how it may be changed, and the influence of the final products upon fertility and growth. It is even possible that during seasons of excess of rain, humidity and cloudiness the bacterial flora so differs, from the normal, as to bring about very marked changes in the soil solutions. In other words, may not some of these troubles which are now spoken of as physiological, be due to detrimental products thrown off in the soil solution by a change of the bacterial flora, this change of flora being the result of a somewhat lengthy, abnormal, meteorological period. The writer is of the opinion that detrimental soil products result more probably from the work of the bacterial and fungous flora of the soil than from the excretions of higher plants.

POSSIBILITY OF THE TROUBLE BEING PHYSIOLOGICAL.

The blight occurring as it does in seasons which are somewhat abnormal would suggest the possibility of the whole trouble being what is often spoken of as physiological. Its appearance in unusual seasons, like 1907, in which the rainfall was in excess, the temperature on the whole extremely low, with now and then a bright, hot day, though as a rule cloudy weather prevailed, would suggest the possibility that these unusual weather conditions brought about an environment unsuitable for the oat crop, resulting in the peculiar yellowing and later in the collapse, so characteristic of the blight. This would suggest a trouble similar to the tip reddening, which may be brought about by a water-logged soil, or an improperly aerated root system. The writer carried out two experiments in the hope of obtaining data along these lines. These experiments were run simultaneously, one under cold or cool conditions, while the second was run under warm conditions. In both, the oats, as soon as the second blade showed, were kept excessively watered and on a part of each bed bacteria of the oat blight were placed on the roots. The results were quite different in the two experiments. The oats kept in the warm house and excessively watered showed a general tip reddening or blight from which no blight bacteria could be cultured; this condition was equal on those infected at roots and those not infected. In the oats growing under cold temperature, very little of this tip reddening could be found; and what did show, produced no bacteria when cultured. This tip reddening from excess of water and non-aeration of soil, may often be observed in

fields where much water has stood. It differs so greatly from the bacterial blight as to be quite easily distinguished. That this general (bacterial) blight is not due physiologically to non-aeration of the soil is readily seen by the conditions prevailing in the fields. As a rule the blight makes its appearance first on the higher grounds as observed by the writer in 1908 and 1909. Van Hook made similar observations in 1907 (see p. 100) and also C. J. Metcalf (see extract from letter, p. 97).

If lack of drainage was the chief factor, the lower areas should first show the blight.

It is well known that excessively low temperatures will bring about abnormal coloration of leaves; such discolorations are everywhere present following the first few cold days of fall. The extremely low average temperatures prevailing throughout the growing season of 1907 were thought to have had much to do in bringing on the unusual blight of oats that season. That such a conclusion based upon this as the chief factor will hardly hold, we discover, when we compare the temperature of the growing season of 1890 with that of 1907, in which former year the blight was much more severe. The data here follow, + = above, and — = below normal average:

	April	May	June	July
1890	+1.5	—1.4	+3.8	—0.2
1907	—7.2	—6.8	—4.0	—1.3

Since the appearance of blight in its severity is generally a matter of the weather conditions prevailing throughout the month of June, we can here readily see that the greatest blight season followed under average high temperatures.

BLIGHTS FROM HELMINTHOSPORIUM SPECIES.

Very often young oat plants show lesions of a brownish purple color, which are due to a Helminthosporium sp., or probably two different species. The first of these appears on seedlings, at the time when the plantlets have only two or three blades (see Fig. 1, Plate XII). This trouble in certain seasons affects many of the seedlings, sometimes as high as 16 percent (see note in description opposite Plate XII), causing a limited injury. The second Helminthosporium blighting is really only a spotting of the oat blades at the time when plants are six inches to 20 inches high. The spots are usually ¼ to ¾ inches long and ⅛ to ¼ inches wide. Such spots cause little or no injury to the plants, and may be passed by with little concern (see Figs. 2 and 3, Plate XII).

DESCRIPTION OF PLATE IV.

Showing in the illustration at the left and center two species of grain aphides at work on oats, at the right is shown the type of injury resulting from aphis sucking; this injury differs entirely from the brown bacterial blight. The aphides here shown are free from, that is, not carrying, the bacteria which produce the blight of oats. The oat blades here illustrated were taken from the cage shown in Plate III at the time when the plants were seven weeks old. Enlarged four diameters.

3-26-09. Original.

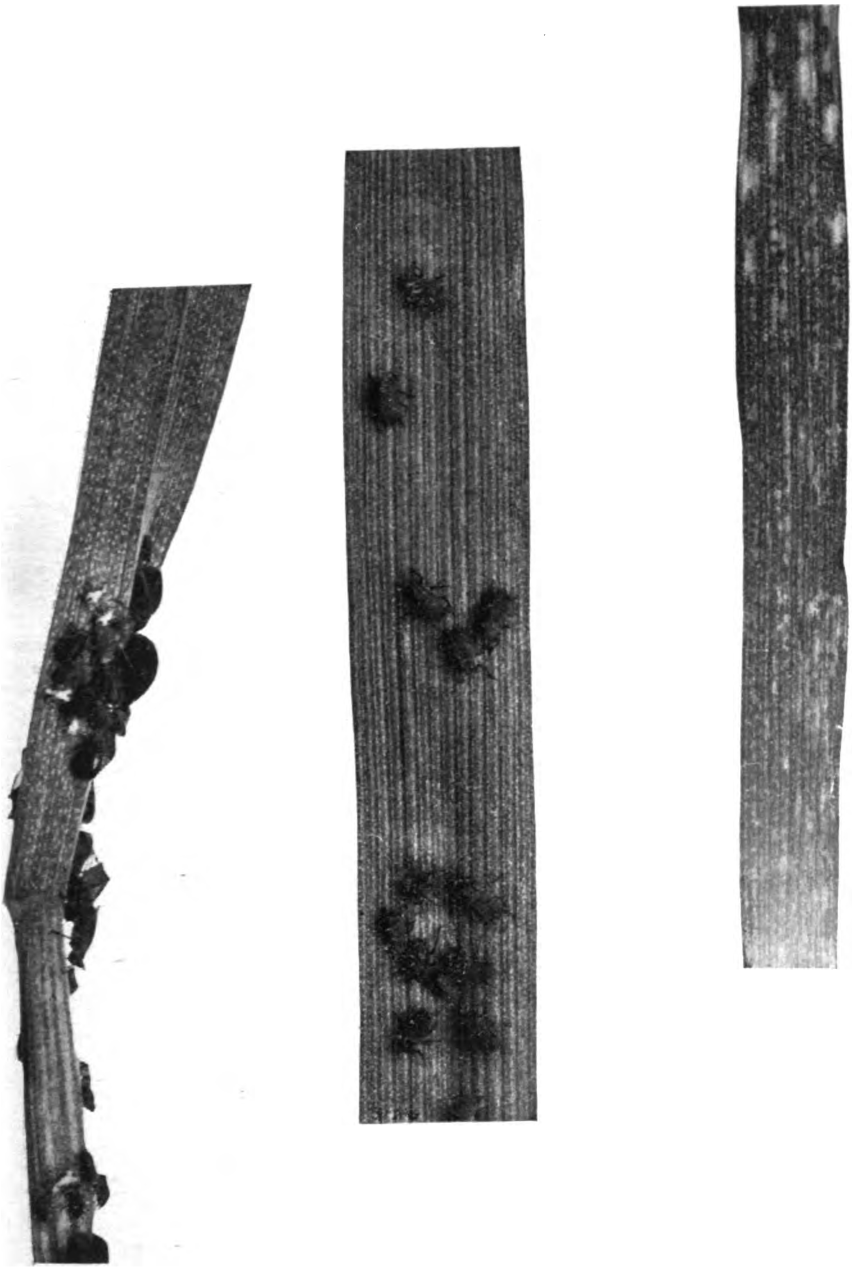


PLATE IV.

DESCRIPTION OF PLATE V.

1. Showing colonies of the bacteria of oat blight taken directly from a yellowed oat blade, culture three days on nutrient glucose agar. The colonies are too much crowded to make further growth. A mixture of these organisms when inoculated into oats produced the blade blight.

2. Showing colonies of the bacteria of oat blight taken directly from a live aphis. Mixtures of these organisms when inoculated into oats gave the typical blade blight, thus showing that the grain lice carry at times viable organisms of the oat blight. Cultures three days old on nutrient glucose agar. Both plates by seven-eighths.

6-10-08. 7-13-08. Original.

1.

2.

PLATE V.

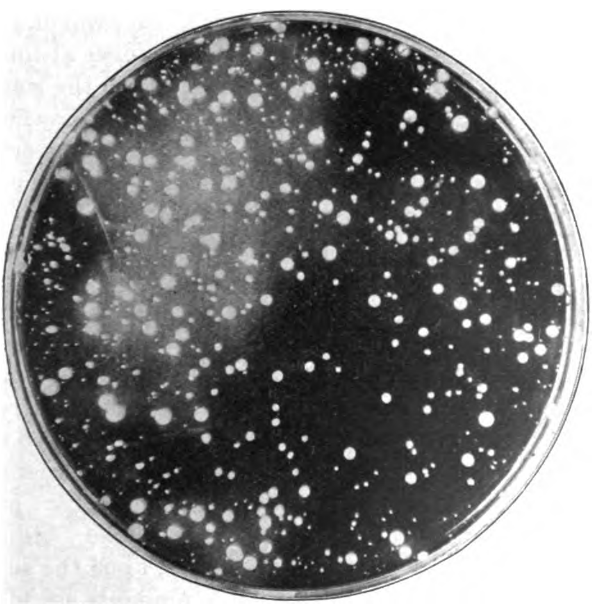
DESCRIPTION OF PLATE VI.

1. Showing a plate culture of the white bacterium (*Pseudomonas avenae* n. sp.) of oat blight on nutrient glucose agar, .5 percent acid to phenolphthalein, in moist chamber six days at 20° C. The graying or fogging of this medium is characteristic. The spreading of the colonies at the bottom of the plate is likewise characteristic.

2. Showing a plate culture of the yellow bacterium (*Bacillus avenae* n. sp.) of oat blight on nutrient glucose agar, .5 percent acid to phenolphthalein, in moist chamber four days at 30° C. The yellow pigment in this organism becomes more or less pronounced as the medium is changed from alkalinity to acidity. Both plates by four-fifths.

3-22-09. 3-20-09. Original.

1.



2.

PLATE VI.

Nematodes occasionally cause a yellowing in seedlings of oats followed by a dying, through their destruction of the stem or root one-half to one inch below the soil. Each of these oat troubles may be easily distinguished from the bacterial blade blight.

KINDS OF INJURY RESULTING TO OATS FROM THE BACTERIAL BLIGHT.

The different manifestations of the disease depend much upon the age and the part of the plant attacked. Observations and experiments made by the writer tend to show that the disease is most specific on the parts of the plant above ground. In the infection work carried out in the pathologium, the writer failed to produce the disease by placing the organisms on the roots. Observations in the field, though not fully substantiating the results of these experiments show however, that among seedling plants, but few become infected by way of root, or that portion of the stem which is underground. In plants beyond the seedling stage it is quite common to find the yellowing lesions following the stem and extending to the very tips of the leaves, sometimes affecting only one side of the blades, and again yellowing the middle or the whole of the blades (see Plate XIII). Just where these lesions begin is sometimes difficult to tell; often they are found beginning on the culm, but more often they originate in the blade and work backwards to the stem. There is no doubt, however, that the disease does at times start in the roots, or that part of the stem in contact with the soil. In older plants it is quite common to find the whole plant showing a general collapse of the foliage, resulting from the disease working backwards into the stem from an early infection of the lower leaves. In many cases of this kind collapse of the upper leaf-tips may occur when bacteria are not present in them; they are, however, present in the lower leaves and lower culms. The usual appearance of the disease is that of a primary yellowing of the blades, which sooner or later is changed to a mottled red and brown. This latter coloring results as the leaves collapse. Sometimes this latter stage, in extreme cases, gives the field the appearance of a severe attack of rust, described by correspondents in the phrase "as red as fire."

This bacterial blight disease is one of the causes of blast in oats. The following data show how directly proportional is the blast of oats to the amount of blade blight. These counts were made during the season of 1909, upon the several varieties of oats and barleys under varying amounts of blight, in the variety plots at the central farm of the Station at Wooster.

Variety	Amount of blade blight	Percent of kernels blasted in the head	Percent of sound kernels in the head	Yield per acre 1909
Improved Am. Oats	Average condition—little blighted	17.2	82.8	73 51
Wide Awake Oats	Average condition—considerably blighted	35.8	64.2	55 42
Wide Awake Oats	Where little blighted	12.8	87.2	.....
Wide Awake Oats	Where quite extensively blighted	22.5	77.5	.....
Wide Awake Oats	Where badly blighted	50.6	49.4	.....
Oderbrucker Barley	Av. condition—Very little blighted	6 1	93.9	37.81
Princess Barley	Av. condition—Noticeable though not bad	28.8	71.2	24.64
Primus Barley	Av. condition—Bad, generally blighted	70.8	29.2	9.01

Observations this season (1909) supported by culture work, show that the heads may be partly or wholly blasted by lesions coming in contact with them. These lesions often begin on the flag leaf and work downward, affecting the head differently, according to its maturity (see Plate XIV), that is, heads entirely covered in sick sheaths are so blasted that they fail to push out at all; others which are just ready to push out at the time when the sheaths become affected, will show more or less blasted kernels. Often the head is halfway out before any part of it comes in contact with the sick sheath, in which case the lower half of the panicle becomes blasted.

The greatest loss to oats from the bacterial blight is due to the injury and collapse of the blades, causing a lowered vitality, with an increase of blast. This injury results, as a rule, from primary infection through the stomata of the sheaths and blades. A smaller loss results from a direct blasting of the heads, due to sheath lesions coming in contact with them. It is also very probable that such specific bacteria, when present in the soil, give rise to products which are detrimental to the oat crop. Just what consequences would result to oats growing in a soil medium filled with such specific organisms as the oat blight bacteria, would be difficult to predict. If the specific lesions in oats result from the effect of a toxin or a destructive enzyme produced by the blight bacteria, then, were these organisms abundant in the soil, it would be reasonable to suppose that the oats would suffer from taking up their specific products. Such may be the very conditions which are actually taking place in those fields showing blight for several seasons successively. This is a phase of soil investigation which should certainly be covered, that is, whether an abundance of these specific organisms in the soil plays a detrimental role against the growth and maturity of oats. *That there is a specific abnormal condition of the oat crop*, is evident from the many observations noted in

the literature quoted. This diseased condition is worse in certain localities than in others, and varies even in fields but little affected. There seems to be some evidence which indicates that these blight organisms in certain small areas, in fields showing limited infection, bring about a condition in the soil which is objectionable to the growing oat plant; if such is the case these areas may be called "oat-sick."

STUDIES IN LIMITING THE ORGANISMS OF OAT BLIGHT.

The field observations noted, and the cultural work herein covered, extend over a period of the past two years. The observations in the field include those of the two growing seasons of of 1908 and 1909, supplemented by the observations made by Prof. Selby and his assistant, J. M. Van Hook, in 1907. The artificial inoculations have been run on six different occasions for periods varying from three weeks to three months, under varying weather conditions. The results all point to the same conclusion, namely, that the disease is caused by the symbiotic relation of two bacteria. During the season of 1908 artificial inoculations in oats in field plots conclusively showed that the yellow organism (*Bacillus avenae*) did not produce lesions, and that the white organism (*Ps. avenae*) would produce but very limited lesions, but when a mixture of these organisms, made directly from crushed leaves, was inoculated, the lesions spread rapidly. This same line of work, duplicated in the pathologium under varying moisture and temperature, gave under favorable conditions exact duplicate of the field work. No typical blight resulted unless both organisms were inoculated into the same plant, conclusively showing the above deductions. The white organisms (*Ps. avenae*) when inoculated alone produced a limited lesion which was light in color and not typical of the lesions of oat blight; since the yellow organism (*B. avenae*) when inoculated alone failed to produce any lesion at all or to make any signs of headway, the active agent in the production of the pathogenicity is *Ps. avenae*. The relation of the yellow organism to the spread of the lesion seems to be that of maintaining a proper nidus for a virulent growth and production of the active toxin or enzyme by the white organism.

A series of plate cultures, run for the purpose of determining the rate of distribution of the organisms throughout the leaf, tends to show that the lesion when the yellow organism is present spreads even more rapidly than do the organisms. That is, yellowing which extended clear to the ends of the leaves often failed to show the yellow organism at all when cultures of the tips were run, and in many instances would show only a few colonies of the white organisms (*Ps. avenae*). In the case where the white organism was

inoculated alone this relation of the bacteria to the spread of the lesion was entirely different, the lesion extending only the distance of the spread of the organism. This line of work would seem to show that the association of the two organisms results in a much more rapid production and spread of the toxin or other products which cause the breakdown of the chlorophyl or the destruction of the cellular work of the leaves. This series of culture work was carried out as follows: Leaves which showed yellowing six to nine inches from the point of inoculation were placed in cultures, using a one-half inch section of the leaf one inch distant from the point of inoculation, and another section six to nine inches from the point of inoculation. In all the plates made from the sections one inch from the point of inoculation, both the yellow and white organisms were found in abundance, while in those plates made from the tip sections of the leaves at a distance of six to nine inches from the point of inoculation, in many there was little or no evidence of the yellow organism and in several of the plates no colonies of the white organism, showing that the lesions are some times more extended than the bacteria.

CHARACTERISTICS OF THE WHITE BACTERIUM OF OAT BLIGHT.

Pseudomonas avenae n. sp.

Following Migula's classification and the numerical system* this organism becomes Ps. 111.2223032.

MORPHOLOGY.

This organism, taken from 24 hour cultures on any of the ordinary culture media, is a bacterium of short, rod shape with round ends, and with few internal markings, having a diameter of .5 to 1 micromillimeter and a length of 1 to 2 mmm. The majority of the organisms measure about ¾ mmm. in diameter, having a length of 1.5 mmm. In hanging drop the flagellate individuals are actively motile, though being limited in number even in the most viable cultures. Occasionally in plates of nutrient agar and in old nutrient glucose agar cultures, the organisms are much shorter, assuming oval or nearly coccus forms. In agar-hanging-block-mounts the organisms separate quickly upon division, very seldom being found in chains of three or four.

Staining Reactions: The organism does not retain Gram's stain.

Endospores: Bodies which are apparently endospores are found in old cultures of the organisms such as those which have run for one month or more. When mounts of such cultures are made, especially those from nutrient glucose agar, and stained with hot carbolfuchsin for three or four minutes, these bodies retain the stain similar to spores. (See Fig. 2, Plate IX). In type, they are

*See Descriptive Chart, endorsed by the Society of American Bacteriologists, December 1907.

similar to the spores found in the anthrax organism, *Bacillus anthracis*. When stained with hot carbolfuchsin they may be decolorized for a few seconds with 5 percent sulphuric acid without losing the stain. Observations were not made as to the growth from these bodies, though cultures which had run nine months before transferring and which had dried up, produced a growth of the white organism, tending further to show that the organism is carried over by more than the vegetative form. Clostridium forms may be observed in nutrient glucose agar in one week old cultures.

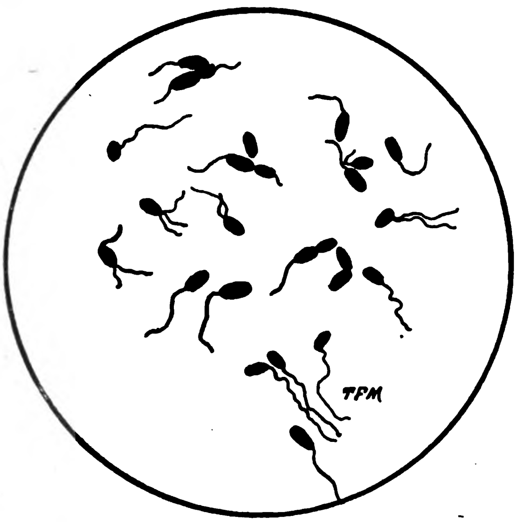


Fig. 1. *Pseudomonas avenae* n. sp. The bacterium which is the active agent in the cause of oat blight. Culture three days on nutrient glucose agar. Drawn from Van Ermengem's stain.

Staining for Flagella: This organism is very difficult to stain in demonstration of the flagella. The film on cover slip appears to fix poorly and in many attempts the film loosens. This is especially true in the use of Van Ermengem's stain, but not so marked in the use of Pitfield's or Muir's modification of Pitfield's. In the use of the two latter stains, though the film holds fairly well, it is found upon examination that the flagella are delicately stained and also very scarce unless one is fortunate in fixing and equally so in catching the growth before the flagella have been cast off. Much difficulty is met with in attempting to limit the number of flagella. In general only one polar flagellum is present. After a careful study of a number of slides, covering over a month's work on staining, the writer has concluded that there is found occasionally individuals having two or three polar flagella, but these are very few (see Fig. 1. p. 134). The cultures have been carried out in triplicate, using the organism from different sources and the work being run at different periods of time. This work on limiting the organism through cultures began in January 1909, and continued through June.

CULTURAL CHARACTERISTICS.

Plate work: Little difficulty is met with in obtaining the two organisms of oat blight as a mixture from the sick blades. The writer sterilized the blades externally with a solution of corrosive sublimate made with two grams of bichloride of mercury in 1000 cc. of equal parts of commercial alcohol and water. The leaves were placed in this solution for one to one and one-half minutes and were then quickly followed by four washings with sterile water. This disinfection in no way apparently injured the organisms which were internal, but proved very efficient in destroying surface contaminations. When mixed the two organisms make a medium to rapid growth and in two to three days they can be plainly seen. Sometimes the yellow organism predominates, but as a rule the white bacterium, when growth takes place properly, is the predominating organism in numbers, though the yellow organism is always the first visible and in some instances, when the medium is slightly unfavorable to the white organism, it may in growth overwhelm the latter. Medium that has become too much dried out is very unfavorable for the white organism (*Ps. avenae*). The growth of the white organism as a whole, when taken in pure culture, is somewhat feeble on the ordinary artificial media, and a number of transfers seem to reduce its viability greatly, so that in many instances it fails altogether to make growth. The culture media most suitable for continued growth appear to be nutrient glucose agar and nutrient saccharose agar.

Agar stroke: Growth very slow, usually visible in three or four days, scanty to moderate, filiform, rather flat, glistening, with margin smooth, opaque to opalescent, non-chromogenic, with little or no odor, having a slimy consistency. The medium, as a rule is turned slightly gray.

Potato plug: Growth moderate, spreading, at first glistening, later dull, smooth, non-chromogenic, no odor, of a slimy consistency.

Agar stab: Growth best at the top, though very thin, white and widespread. Line of puncture filiform, slightly beaded near top, growth soon limited in the deeper medium.

Gelatine stab: The line of puncture becomes visible about the third day. Growth is best at the top and is somewhat limited along the stab, the line of puncture is filiform and slightly papillate. Liquefaction is crateriform and begins in seven to twelve days. In two weeks liquefaction has covered about the upper one-third of a two inch culture (see Fig. 2, Plate VIII); in sixty days the liquefaction is complete. The precipitate is a grayish light yellow.

Nutrient broth: Visible growth is present in three days. Medium slowly clouds with no flocci or pellicle, clouding moderate and persistent, odor resembling decay by *B. subtilis*, Sediment scant but compact, very light yellow.

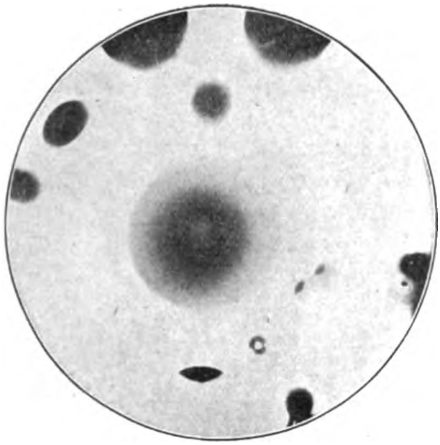
DESCRIPTION OF PLATE VII.

1. Showing a surface colony of the white bacterium (*Pseudomonas avenae* n. sp.) of the oat blight in nutrient glucose agar culture; six days at 22° to 23° C. Enlarged seven and one-half times.

2. Showing a sub-colony of the white bacterium of oat blight in nutrient glucose agar plate culture; six days in moist chamber at 22° to 23° C. Enlarged 65 times.

3. Showing sub-colony of the white bacterium of oat blight differing somewhat in shape from the colony illustrated in (2) above. In nutrient glucose agar plate culture; six days at 22° to 23° C. Enlarged 65 times.

4. Showing a sub-colony of the yellow bacterium (*Bacillus avenae* n sp.) of oat blight in nutrient glucose agar plate culture; four days at 22° to 23° C. Enlarged 65 times. (All taken 5-18-09). Original.



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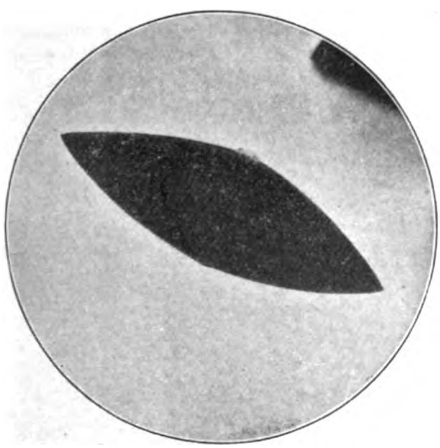

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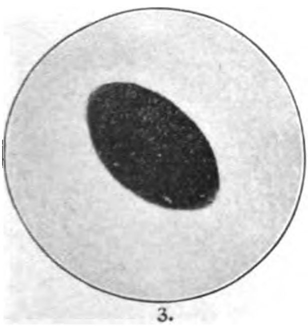

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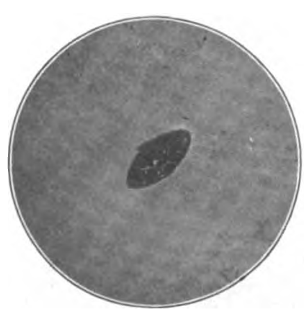


4.

PLATE VII.

DESCRIPTION OF PLATE VIII.

1. Showing a gelatine stab culture of the white bacterium (*Pseudomonas avenae* n. sp.) of oat blight one week old; temperature 22° to 23° C. (Medium .5 percent acid to phenolphthalein). Natural size. 3-30-09.

2. Showing a gelatine stab culture of the white bacterium (*Pseudomonas avenae* n. sp.) of oat blight two weeks old: temperature 22° to 23° C. (Medium .5 percent acid to phenolphthalein). Natural size. 4-6-09.

3. Showing nutrient glucose agar (.5 percent acid to phenolphthalein) slant culture of the white bacterium (*Pseudomonas avenae* n. sp.) of oat blight, temperature 22° to 23° C.; two weeks old. 3-21-09.

4. Showing a gelatine stab culture of the yellow bacterium (*Bacillus avenae* n. sp.) of oat blight two weeks old in medium .5 percent acid to phenolphthalein. Temperature 22° to 23° C. 3-30-09.

5. Showing a potato plug culture of the yellow bacterium, (*Bacillus avenae* n. sp.) of oat blight. two weeks old at temperature 22° to 23° C. 3-27-09.

6. Showing nutrient glucose agar (1.5 percent acid to phenolphthalein) slant culture of the yellow bacterium (*Bacillus avenae* n. sp.) of oat blight; one week old at temperature 22° to 23° C. 3-19-09. All original. Natural size.

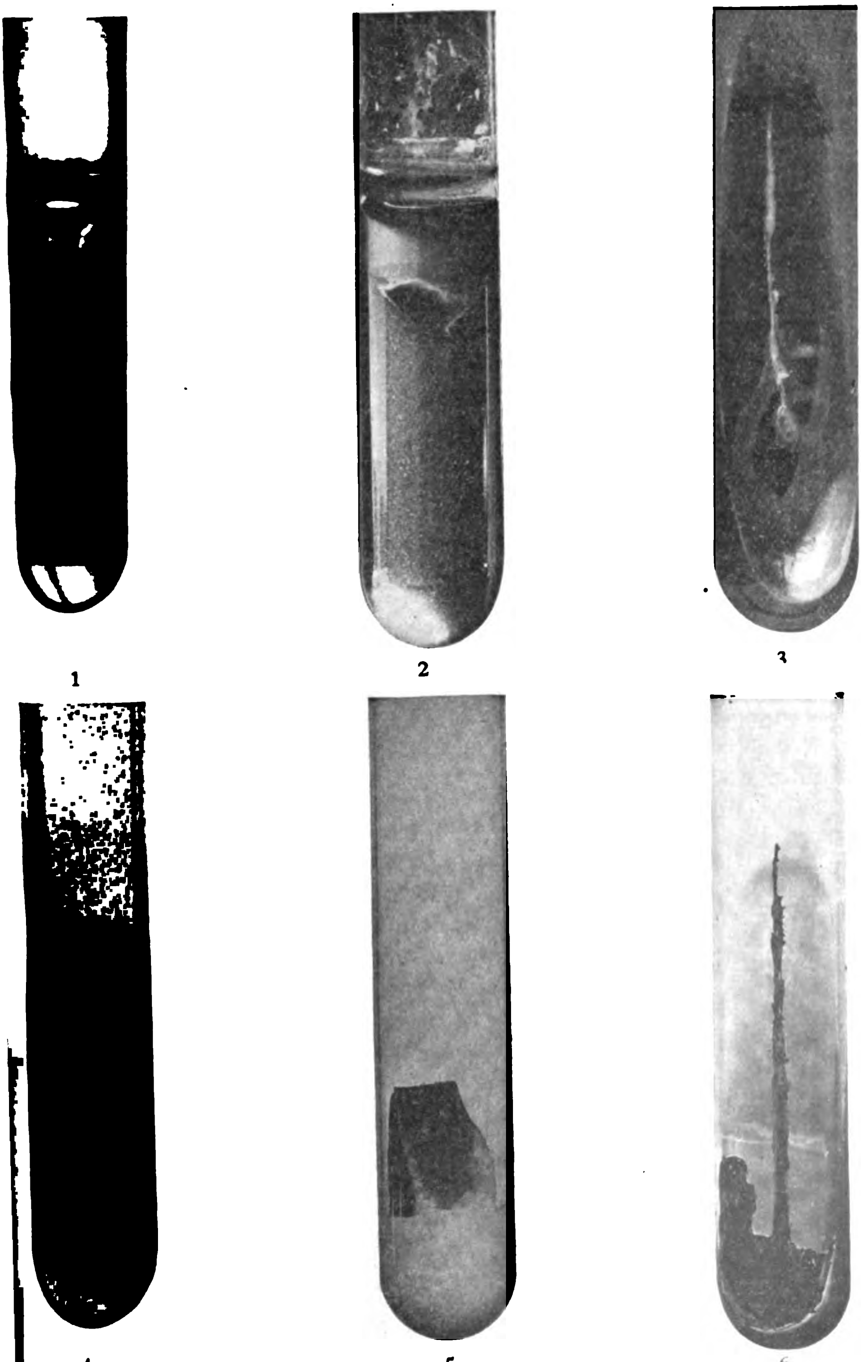


PLATE VIII.

Milk: No coagulation in thirty days. The reaction is slightly acid and apparently remains so.

Litmus milk: Beginning with the second day the medium shows a very slight acidity which gradually increases up till the 10th day, after which the acidity begins to weaken; no coagulation.

Gelatin colonies: The growth is somewhat slow, colonies becoming visible about the second to the third day. At the end of the 7th day pitting is noticeable. The colonies at three days are white to gray, round, with margins entire; in two to three weeks the pitted colonies become confluent and liquify this medium.

Agar colonies: Growth is very slow; colonies are visible about the third day. Colonies round with smooth surface and edges entire. The internal structure is amorphous, somewhat more dense at center.

Growth: Growth takes place best on nutrient glucose and saccharose agar.

PHYSICAL AND BIOCHEMICAL FEATURES.

Gas and acid production: No gas is produced in the following sugar bouillons: dextrose, saccharose, lactose, maltose and glycerin. Little or no growth takes place in the closed arm of the fermentation tube. The production or change in acidity in each of the above media is as follows. Dextrose, check 1.5 percent acid to phenolphthalein; first day's growth 1.25 percent, second day's growth 2. percent, fourth day's growth 1.82 percent. Saccharose bouillon, check 1.9 percent acid; growth shows no change in four days. Lactose, check, 1.75 percent acid; first day's 1.37 percent, second day's 1.75 percent, fourth day's 1.25 percent. Maltose bouillon, check, 1.87 percent acid; first day's growth 2.25 percent, second day's 1.75 percent, fourth day's 1.57 percent. Glycerin, check, 1.5 percent acid; first day's growth 1.42 percent, second day's 2. percent, fourth day's 1.51 percent acid. These variations are very slight and the conclusions would seem to be that the white organism, *Ps. avenae*, produces but very little change in the reaction of media.

Ammonia: None produced.

Nitrates: Reduced to nitrites in nitrate bouillon.

Indol: No indol is produced,

Tolerations of acids and alkalies: This organism is very sensitive to alkalies, producing only limited growth in .5 percent alkaline medium (to phenolphthalein), and likewise on the other hand it is quite sensitive to acids, making but little growth on medium beyond 1.5 percent acid to phenolphthalein. The optimum reaction for growth appears to be about +10 in Fuller's scale.

Vitality on media: When grown on nutrient glucose agar, and nutrient saccharose agar, the vitality of this organism is quite pro-

longed. Its life on culture media appears to be a matter of spore production, which latter apparently form after several weeks on sugar media.

The thermal death point in young cultures is reached in a ten-minute exposure at 60° C.

The optimum temperature for growth is between 20° and 30° C.

Light is very active in checking the viability of this organism.

Drying quickly kills the organism in young culture, though in old cultures the spores apparently carry it over.

Effects of germicides: This organism in the vegetative state is much more susceptible to germicides, heat, light and drying than is the yellow organism. Killing results in ten minutes in a 1 in 15,000 solution of corrosive sublimate, or 1 in 7,500 of formaldehyde. In a toleration test in nutrient glucose bouillon having one gram of corrosive sublimate in 75,000 cc. and when 1 cc. of formaldehyde in 15,000 cc. was used, the organism failed to grow.

Pathogenicity: Pathogenic in blades of oats (*Avena sativa*), corn (*Zea mays*), timothy (*Phleum pratense*), barley (*Hordeum distichum*), wheat (*Triticum vulgare*), and in the culms and sheaths of the blue grasses (*Poa pratense* and *P. compressa*).

DESCRIPTION AND CHARACTERISTICS OF THE YELLOW BACTERIUM OF OAT BLIGHT.

Bacillus avenae n. sp.

Following Migula's classification and the numerical system* this organism becomes B. 222.2223532.

MORPHOLOGY.

This organism when grown on nutrient glucose agar at room temperature 22° to 23° C., for twenty-four hours is a very actively motile bacillus of short, rod shape with rounded ends, measuring from .75 to 1 x 1.5 to 2 micromillimeters. The majority are about .75 mmm. x 1.7 mmm. Division when observed in agar hanging block takes place quickly, the organisms soon separating; usually found singly, but some times observed in short chains of three or four.

Staining reactions: This organism does not retain Gram's stain.

Endospores: No endospores have been observed.

Flagella: The flagella are many, peritrichiate, long, undulate; easily stained with Pitfield's or Van Ermengem's method.

CULTURAL FEATURES.

Agar stroke: Growth is very rapid and abundant. Filiform, slightly raised, at first white, glistening, later turning somewhat dull, margin smooth, growth rather opaque; the third day turning yellow; growth somewhat mucous: no noticeable odor.

Potato: Growth abundant and persistent, rapidly spreading; diffuse, dull, margin smooth; pigment yellow. Consistency mucous. No characteristic odor.

*See footnote p. 133.

DESCRIPTION OF PLATE IX.

1. Showing the white bacterium (*Pseudomonas avenae* n. sp.) of oat blight from nutrient glucos agar plate, ten days in moist chamber. Carbolfuchsin. Enlarged 1000 times. 4-3-09.

2. Showing what appear to be spores of the white bacterium (*Pseudomonas avenae* n. sp) of oat blight from a two months old culture on nutrient glucose agar stained with hot carbolfuchsin four minutes and decolorized with 5 percent sulphuric acid. Enlarged 1000 times. 5-17-09.

3. Showing polar flagella of the white bacterium (*Pseudomonas avenae* n. sp.) of oat blight from a twenty-four hour culture on nutrient glucose agar. Pitfield's stain. Enlarged 1000 times. 5-19-09.

4. Showing polar flagella of the white bacterium (*Pseudomonas avenae* n. sp.) of oat blight from a twenty-four hour nutrient glucose agar slant. Pitfield's stain. Enlarged 2000 times. 5-18-09.

5. Showing flagella of the yellow bacterium (*Bacillus avenae* n. sp.) of oat blight from a four days old culture on nutrient glucose agar. Van Ermengem's stain Enlarged 1000 times. 4-3-09.

6. Showing the yellow bacterium (*Bacillus avenae* n. sp.) of oat blight; culture one week old on nutrient glucose agar. Carbolfuchsin stain. Enlarged 1000 times. 4-26-09. All original.

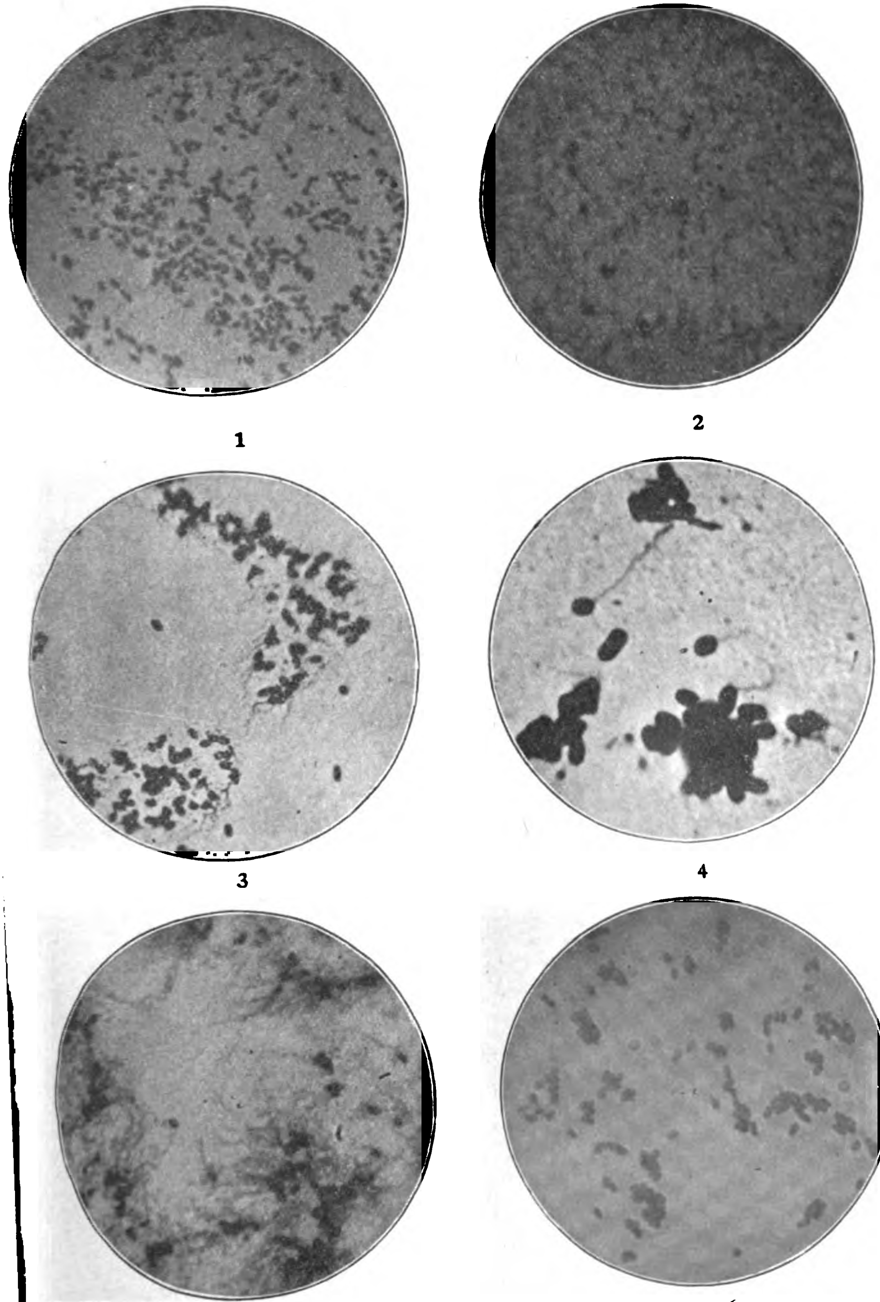
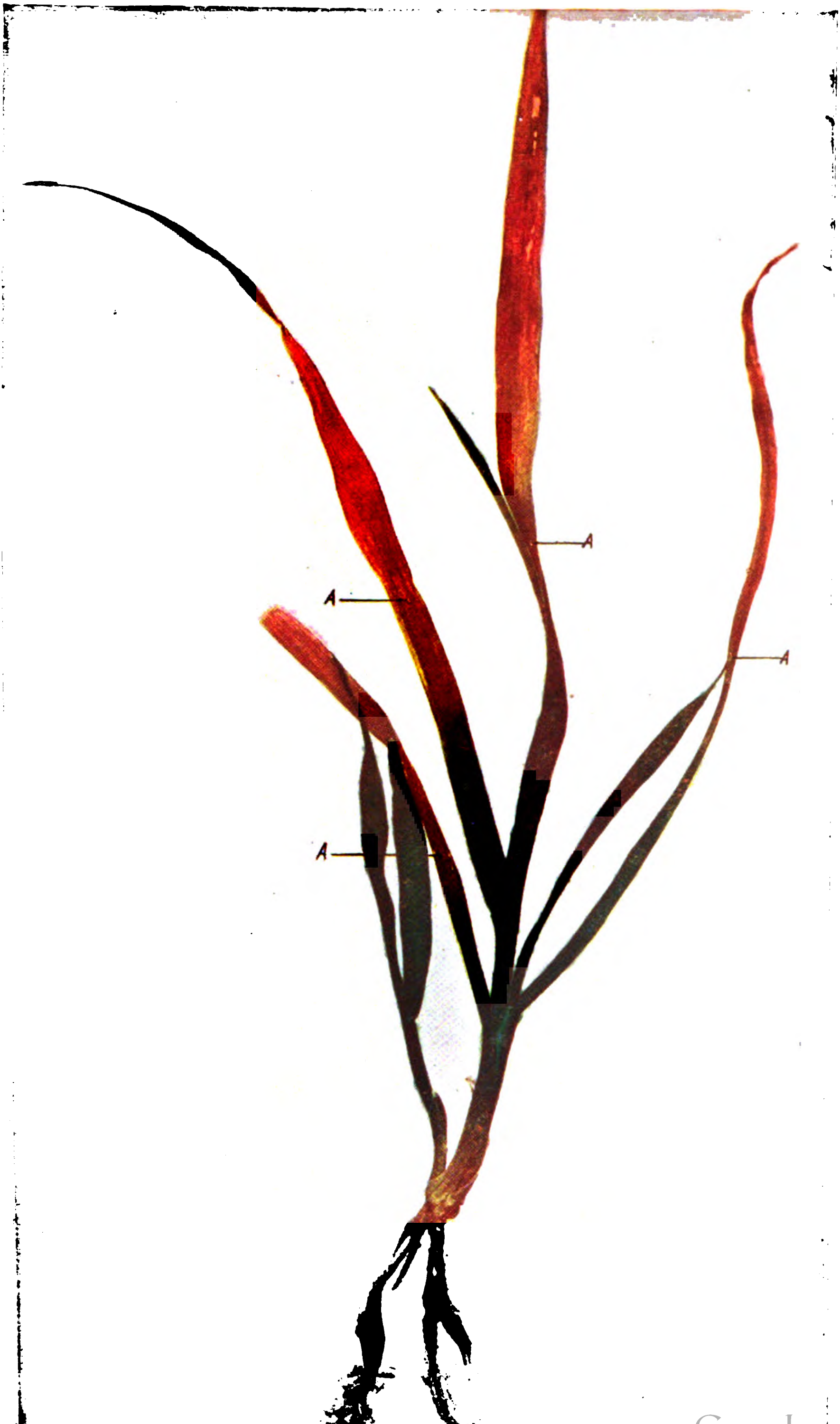


PLATE IX.

DESCRIPTION OF PLATE X.

Showing an oat plant infected with a mixture of artificial cultures of the bacteria (*Ps. avenae* n sp. and *B. avenae* n. sp.) which cause the brown blade blight of oats; inoculated by means of a hypodermic needle at the points marked "A." The preliminary results of the infection is a yellowing extending rapidly to the very tips of the leaves; should a day or so of hot sunshiny weather follow this yellowing, the leaves will quickly assume the characteristic reddish brown color typical of the blight which results in an almost total collapse of the infected leaves. Infection had run two weeks at the time of photographing. Water colored. Natural size. 3-31-09. Original.


A
A
A
A

Agar stab. Growth best at top with an abundant growth at surface. Line of puncture filiform, slightly beaded; growth soon becomes yellow.

Gelatin stab: Growth best at top, filiform and somewhat beaded on upper line of puncture. No liquefaction takes place in four weeks. Growth turns yellow on the third day.

Nutrient bouillon: Medium becomes unevenly cloudy in twenty-four hours. The second day shows a heavy yellow precipitate.

Milk: Coagulation shows at the end of two weeks at which time extrusion of whey begins. The reaction of check was 1.57 percent acid to phenolphthalein. At the end of the second day's growth the reaction was 1.95 percent acid; at the end of the fourth day's growth the acidity was 2 percent. The general consistency of the milk remained apparently unchanged until the end of the second week, when coagulation set in.

Litmus milk: Shows acid at the end of the first day and gradually becomes more marked until the fourth week. Coagulation takes place the second week.

Gelatin colonies: Growth is very rapid; colonies visible in twenty-four hours. Round and slightly raised, edge entire; no pitting or liquefaction. Sub-colonies lenticular.

Agar colonies: Growth is rapid at room temperature; round, with smooth surface, slightly raised; edges entire. Amorphous somewhat denser at center. Sub-colonies lenticular, amorphous though center dense.

Growth: Growth takes place best on nutrient glucose or saccharose agar.

PHYSICAL AND BIOCHEMICAL FEATURES.

Gas and acid production: No gas is produced in the following bouillons: dextrose, saccharose, lactose, maltose and glycerin. Growth is noticeable in the arm of fermentation tube in the dextrose and saccharose, though not marked. There is possibly a slight growth in the closed arm in lactose and glycerin. The production of acid in each of the above media takes place as follows: Dextrose, check, 1.5 percent acid to phenolphthalein, first day's growth 3.8 percent, second day's growth 3.8 percent, fourth day's growth 3.8 percent. Saccharose, check, 1.9 percent, first day's growth 3.2 percent, second day's growth 3.5 percent, third day's growth 3.4 percent. Lactose, check, 1.7 percent, first day's growth 1.7 percent, second day's growth 1.9 percent, fourth day's growth 2 percent. Maltose, check, 1.8 percent, first day's growth 2.5 percent, second day's growth 3 percent, fourth day's growth 3 percent. Glycerin, check, 1.5 percent, first day's growth 1.9 percent, second day's growth 2.2 percent, fourth day's growth 2.2 percent.

Ammonia: No ammonia is produced in nutrient bouillon or in nutrient sugar bouillon.

Indol: Production of indol is moderate in sugar free bouillon.

Nitrate reduction: Nitrates are reduced to nitrites in nitrate broth.

Toleration of acids and alkalies: This organism makes fair growth in 2.5 percent acid medium to phenolphthalein while 1 percent alkaline medium retards its growth.

Optimum reaction for growth in nutrient sugar bouillon or nutrient sugar agar is +15 in Fuller's scale.

Vitality on culture media is long.

The thermal death point is reached in a ten minute exposure at 60° C. The optimum temperature for growth is between 20° and 30° C. Very resistant to exposure in light.

The organism is quite resistant to drying in cultures.

Effects of germicides: Killing results in ten minutes in a one in 10,000 solution of corrosive sublimate or in a one in 5,000 solution of formaldehyde. In a toleration test in nutrient glucose bouillon, growth failed in this medium having one gram of corrosive sublimate in 50,000 cc., and likewise when 1 cc. of formaldehyde in 10,000 was used.

Pathogenicity: The organism is not pathogenic by itself; however, in symbiotic relation with *Pseudomonas avenae* n. sp., it aids in producing the blade blight of oats.

THE POSSIBILITY OF SELECTING RESISTANT STRAINS OF OATS.

A casual examination of different oat varieties at the time when the disease is at its worst would seem to indicate little possibility of selecting a variety having much resistance. However, such a conclusion does not seem to be sustained when yields are considered. The results from the variety oat test at this Station for the season of 1907 (the heavy blight year) gave for the Sixty-Day variety a yield of 56.95 bushels as compared with 54.49, 51.13, 50.63 bushels for the three next higher yielding varieties and with 44.75 bushels for the average of all varieties excluding the Sixty-Day. Van Hook in his correspondence (see p. 100) notes that there existed differences in resistance to the blight disease in the oat varieties being compared here in 1907.

In 1908, the outbreak at this Station was at first most severe among the earliest sowings (some sowings of the early and late test) which were located at the south of the tier including the variety tests. Later, however, the disease appeared to be somewhat general, though not severe, on most of the varieties, appearing to be somewhat more pronounced upon Wideawake.

In the infection work in the pathologium from February to May, 1909, two varieties, viz., Improved American and Wideawake, were used respectively in the different inoculations, and it was quite

noticeable that Improved American was slower on an average to show infection than was Wideawake. Again it was noticeable that a few individuals showed marked difference in resistance from the average. It is from these individuals rather than from any special variety that the writer believes the more valuable resistant selections may come. On the other hand, there is little doubt but that the variety which shows the most resistance will also offer the greatest number of individuals for selection. Observations made this season (1909) indicate that there is some difference in susceptibility to the blight disease as manifested by the amount of infection showing on the different varieties in the test plots at the Station. The strain selected and grown as a winter oat showed no sign of blight this season, as far as the writer could determine. This same strain, when sown as a spring oat, showed but the slightest trace of the disease. On the other hand, Wideawake and several of the other varieties showed a marked beginning of infection at one time. The disease made little or no headway after the advent of sunshiny, dry weather, thus preventing further observations on the spread of the disease, and the resistance of varieties. The writer is fully satisfied that there is a good opportunity for selecting resistant strains which would quite easily overcome much of the losses from this disease.

The following data show the yields of Improved American compared with Wideawake and the average of all varieties grown in the variety oat test at this Station during the past six years[21].

	1904	1905	1906	1907	1908	†1909
Improved American.........	85.66	59.45	87.21	45.47	67.18	73.51
Wideawake..........................	77.26	56.65	73.02	40.20	50.19	55.42
Average of all varieties...	77.75	59.16	77.90	45.25	62.02	65.81

In each of the above years it is apparent that the Improved American variety outyielded Wideawake considerably, also that the average of all varieties exceeds Wideawake in yield. Some of this difference in yield between other varieties and the Wideawake is undoubtedly due to the latter's non-resistance to the blight disease.

BREEDING OF RESISTANT STRAINS AN IMPORTANT PHASE OF EXPERIMENT STATION WORK.

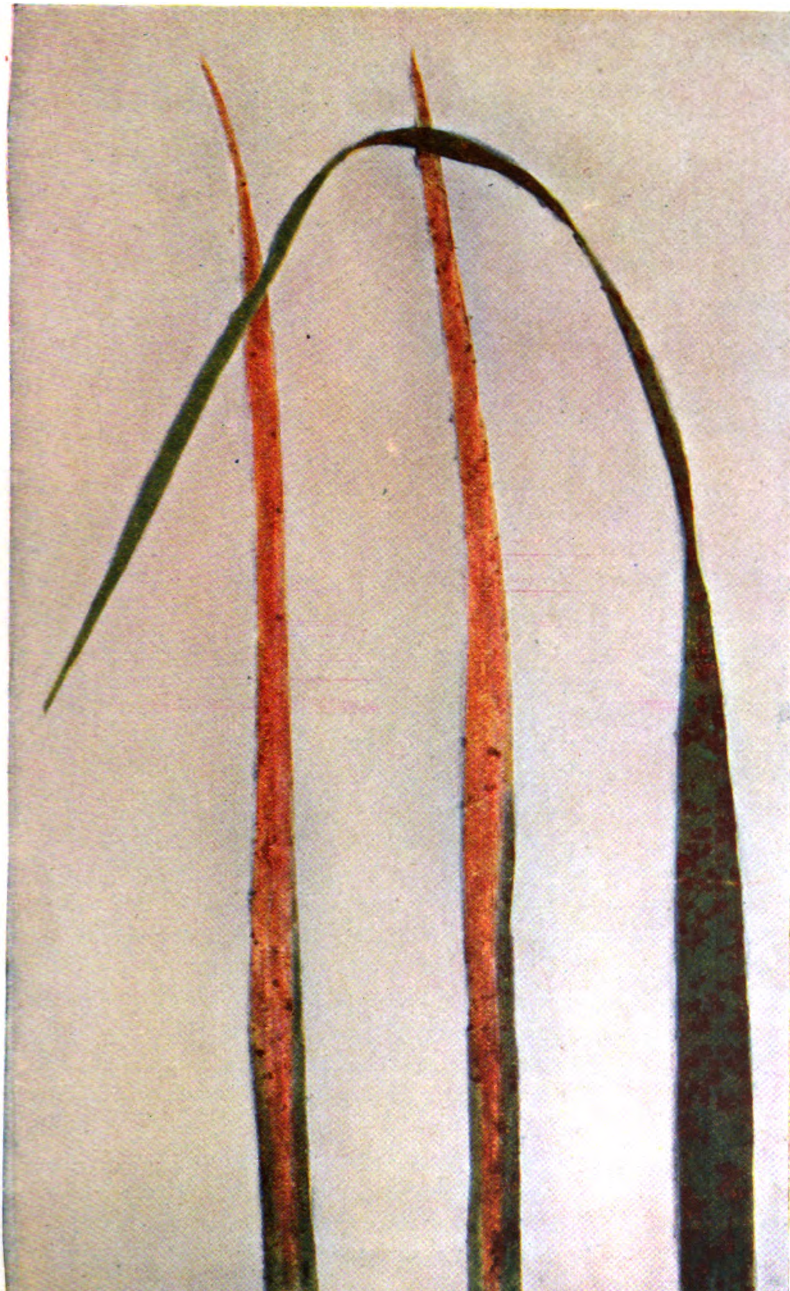
The writer is an ardent believer in the "ounce of prevention" theory. There are, however, two ways in which the agriculturist may considerably ward off plant diseases; one is to be continually on the alert and apply proper treatment at the right time. Should he, however, be trying to grow varieties which are very susceptible to disease, this method is not always the most pleasant and most practical.

[21] Cir. 88, Ohio Agric. Exp't. Sta., Feb. 15, 1909, C. G. Williams.

†From data of 1909 yields furnished by C. G. Williams.

DESCRIPTION OF PLATE XI.

Showing the oat blight resulting from aphides carrying the disease. The two leaves at the left came from the check row, which became infected through the grain lice carrying the disease from the infected row. (See Plate II and the description). The lice were placed on the infected plants of the inoculated row; both rows were then caged in; in two weeks these insects had carried the disease to the check (healthy) row with the bacterial blight resulting as photographed in the two leaves at the left The leaf at the right came from the cage in which the aphides free from the bacterial blight disease were confined (see Plate III and the description). The injuries resulting to oats from the sucking of aphides is entirely different from the blade blight. (See Plate IV). 3-31-09. Original. Natural size



A second means is to secure varieties which are known to be very resistant to the more common diseases. To accomplish the end in view both of these means: resistant varieties and treatment, should be diligently looked after. The value of using resistant varieties or strains is everywhere apparent. Take for example the loose smut of wheat in this state. Observations and examinations show that this disease is causing losses in different fields from less than .01 percent to as high as 5 percent. That such a heavy loss as 5 percent or even 2 percent is simply a matter of unwisely continuing the use of a susceptible variety is very evident. During the season of 1908, the varieties of wheat grown at this Station were carefully counted to estimate the percent of loose smut. Only seven varieties out of some forty-seven showed a loss of over 1 percent due to this disease. Among these seven are to be noted the following: Pride of Genesee 1.08 percent, Prosperity 6.47 percent, American Bronze 5.14 percent, Invincible 5.20 percent, Hickman 1.02 percent, Golden Bronze 1.87 percent, and Dawson's Golden Chaff 1.75 percent. Of the remaining forty varieties, thirty showed less than .5 percent loss from loose smut, and of these thirty, fifteen showed .05 percent or less; five showing practically no loose smut. Among those that show little or no loose smut were some of the best yielders. It is observed that these susceptible varieties show more or less smut every season. During 1908 the writer attempted to infect with loose smut the variety of wheat known as Poole. The result was negative owing to this variety's resistant qualities to the smut disease. The same is true also of oats, barley, flax, potatoes and many other crops in relation to their specific fungous diseases. Some have considerable resistance to plant diseases, possessing also good quality and high yielding capacity.

The time is now ripe when systematic selection of strains from different varieties for resistance to prevalent plant diseases may be made a great economic factor in modern production. The question so often raised, why not let nature have her course and we continually select the most prolific among the survivals, is answered by the remark that nature is much too slow for our generation, also the layman not having the knowledge of conditions favoring and limiting plant diseases, is not in line to control nature; when nature does afford the opportunity he is too deeply concerned in other lines to take advantage of it. Diseases are periodic, that is, they make their appearances irregularly according to whether meteorological conditions are favorable or not; along with favorable conditions must be present not only particular means of infection, that is, the spores or other propagating parts of the disease, but also the host. If nature were regular in her seasons, and similar in her corresponding periods, then the matter of breeding for resistant strains would

be simplified. At present, however, to accomplish ends too difficult for the layman, requires the training of the pathologist. That is, the pathologist having the specific infecting material at hand and knowing the necessary environment for the development of the disease, may and can maintain these, and subject the plant to such each year, instead of waiting for those years having the periodical outbreak of the required disease. The meteorological requirements of certain diseases are now so well known that it is quite possible to keep these diseases active in unfavorable seasons, simply by supplying the necessary conditions. This was readily shown in working with the oat blight in the pathologium during the past winter. Conditions which were unfavorable for the development of the disease were overcome by maintaining a partial shading and a saturated atmosphere.

SOME OF THE NEEDS AND POSSIBILITIES OF SELECTION FOR DISEASE RESISTANT PLANTS.

Work under glass: That the pathologium or properly regulated greenhouse can be of great use in the preliminary testing and selection of resistant strains is very evident to the writer, he having previously made use of such means in testing flax as to its resistant qualities to the flax wilt disease*. For special work of this kind, however, a greenhouse is required with apartments which permit of auto-regulation in ventilation, heating, lighting and moisture. A system which permits such regulation in heating and ventilation is not difficult to install. Likewise moisture conditions may be more or less easily controlled. Even lighting permits partial control. The great advantage of such greenhouse work is evident when with certain plants we can make time in multiplying individuals by growing and maturing an extra crop during the winter, permitting inoculation under favorable conditions for disease production, thus readily distinguishing resistant from non-resistant individuals. Such conveniences would not only give opportunity for preliminary selection, but also the means for testing out supposed resistant individuals, which under field conditions may strike the proper conditions for a test but once in two to five years. Where we start from individual plants and have no further means than nature to bring about proper meteorological conditions for the disease, sometimes we are much disappointed after carrying a good yielding plant several years, to find that it succumbs upon the appearance of certain fungous or bacterial diseases.

* "Fungi of Flax-sick Soil and Flax Seed," 1902-1904. Submitted to the North Dakota Agricultural College, Department of Botany, Feb. 1,1909, for publication.

SOME OF THE LINES ALONG WHICH FURTHER STUDY SHOULD BE MADE ON THE OAT BLIGHT.

The writer is fully convinced that this bacterial blight is the means of bringing about an abnormal condition of the oat crop throughout the eastern and central states. The observations and investigations herein recorded cover but a few phases in the study of this very general and important trouble.

Some suggestions pointing to investigations which would further make clear the relation between the oat blight and the specific organisms which are the cause of this disease, and economic means for the control would not be out of place at this time. Among the more important questions to be settled are the following:

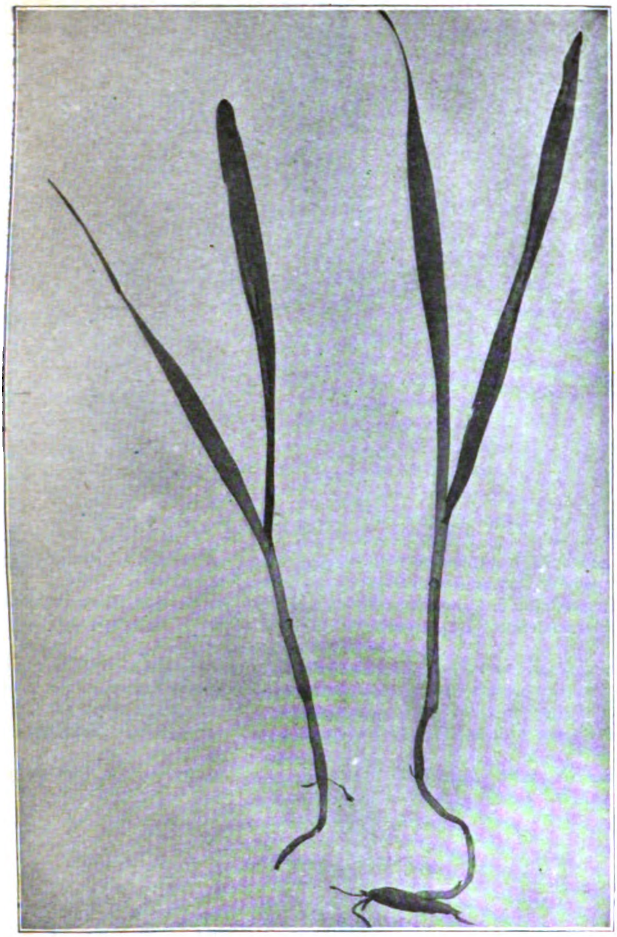
1. Are these specific oat blight organisms common and persistent in soils?
2. If so, do they give rise within the soil to products which are injurious to oats and other crops?
3. If so, are these products easily or difficultly destroyed?
4. To what extent are these blight organisms within the soil responsible for the weakened vitality so conspicuous in oats?
5. What relation exists between blight and blast in oats?
6. In what types of soil and under what meteorological conditions do these blight organisms thrive best?
7. Can this blight trouble be overcome by the selection and breeding of resistant varieties?

DESCRIPTION OF PLATE XII.

1. Showing oat seedlings affected with the Helminthosporium blight. On some of the variety plots of the Experiment Station the affected plants reached 16 percent. The plants, as a rule, quickly outgrow this blight. Enlarged one and one-eighth times. 5-10-09.

2. Showing nutrient glucose agar plate culture of pieces of oat blades infected with the Helminthosporium blight. Observe the fungus coming from the pieces of oats. The soil upon which these oats grew was treated very heavily with a solution of 1 pound of formaldehyde to 20 gallons of water, using one gallon per square foot. The oats were also thoroughly treated with a solution of formaldehyde made with 1 pound to 40 gallons. These treatments either failed to kill the fungus in the soil or on the surface of the seed, or the fungus is internal. Following the above treatment on the variety, Improved American, 9 percent of the seedlings showed infection with this blight. The Wideawake variety showed nearly 11 percent of the seedlings infected. 2-26-09.

3. Showing the under surface of nutrient glucose agar plate cultures of the Helminthosporium fungus coming from pieces of infected oat blades. The sub-medium growth of this fungus assumes a very dark color as illustrated. The aerial mycelium, however, has a gray color. Plates by one-half 3-15-09. All original.



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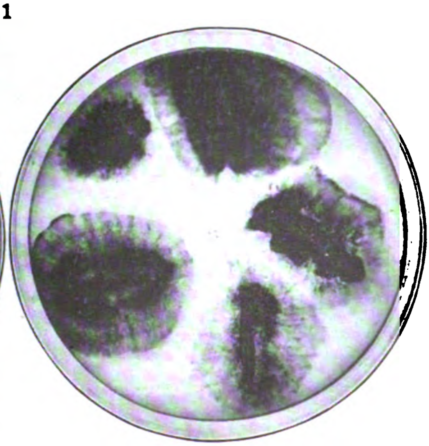

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PLATE XII.

DESCRIPTION OF PLATE XIII.

Showing a photograph of three oat blades in different stages of the bacterial blight (from natural infection) which has in no way been complicated with the work of aphides.

1. Showing preliminary lesions (the larger, light, oval spots) from stomatic infection, spread by rains. The smaller dark spots are caused by a fungus, *Helminthosporium avenae sativae* (*Briosi* and *Cavara*).

2. Showing a general yellowing of the blade due to primary stomatic infection on the stem.

3. Showing partial breakdown of a leaf due to the blight lesions becoming confluent.

NOTE: Illustrations in this plate show separate and distinct lesions. When infection is generally distributed the lesions quickly become confluent, giving the blades a mottled yellowish brown appearance.

(All from the oat variety plots, Ohio Agricultural Experiment Station, Wooster, June 15, 1909).

6-15-09. Original. Enlarged one and one-third times.

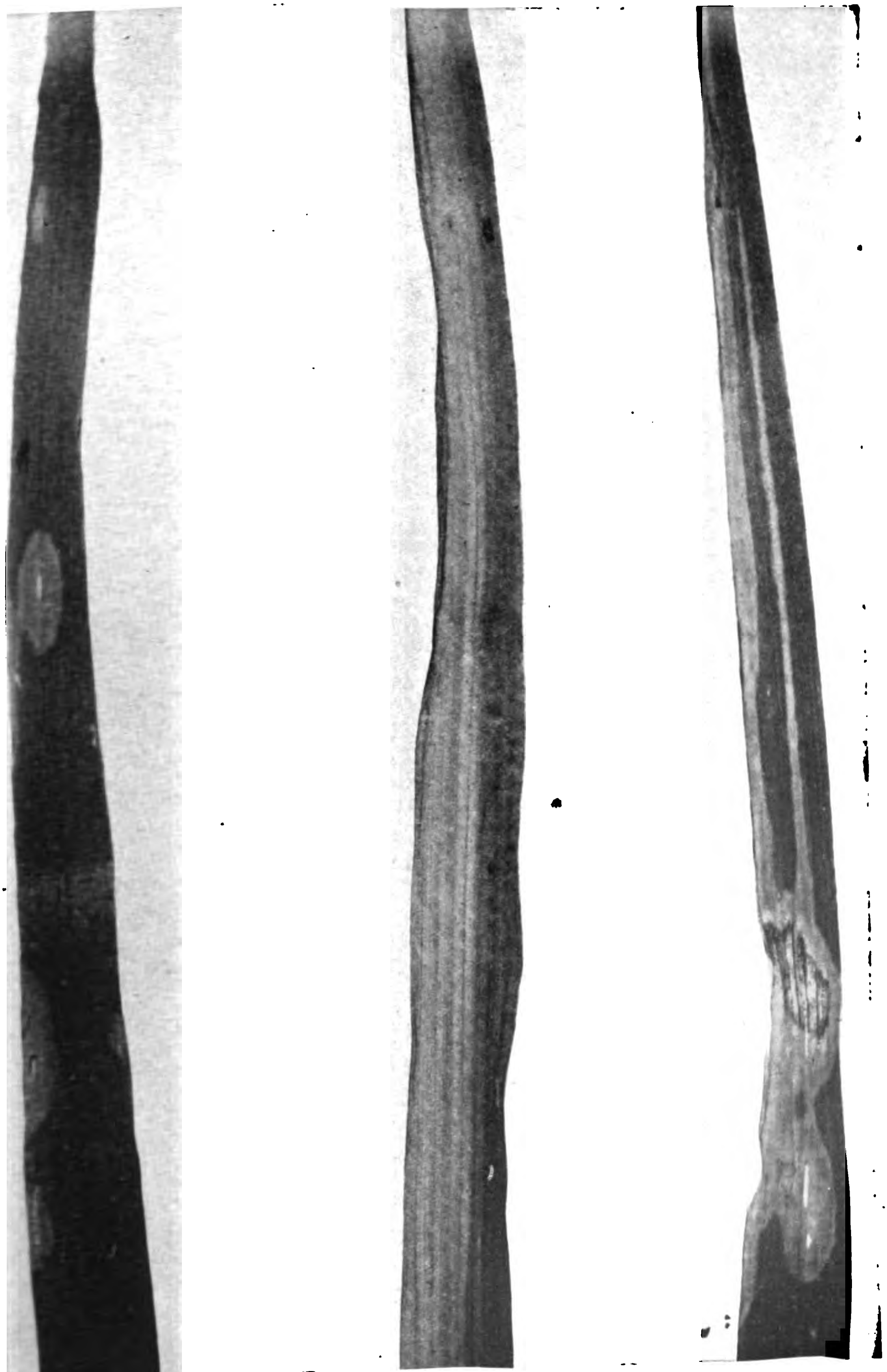

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PLATE XIII.

DESCRIPTION OF PLATE XIV.

Showing the "blast" of oats resulting from the bacterial blight disease (natural infection). In this case the flag leaf had completely collapsed, and the lesion had passed downward attacking and blasting the head. In many cases the panicle was completely killed before it had emerged from the sheath. The small light spots on the lower leaf in the illustration, are beginning lesions of the bacterial blight. This shows the disease resulting from stomatic infection by spattering of rain. The oat plants at this stage were about three feet high; many showed partial collapse due to infection of the lower leaves and culms; by two-thirds.

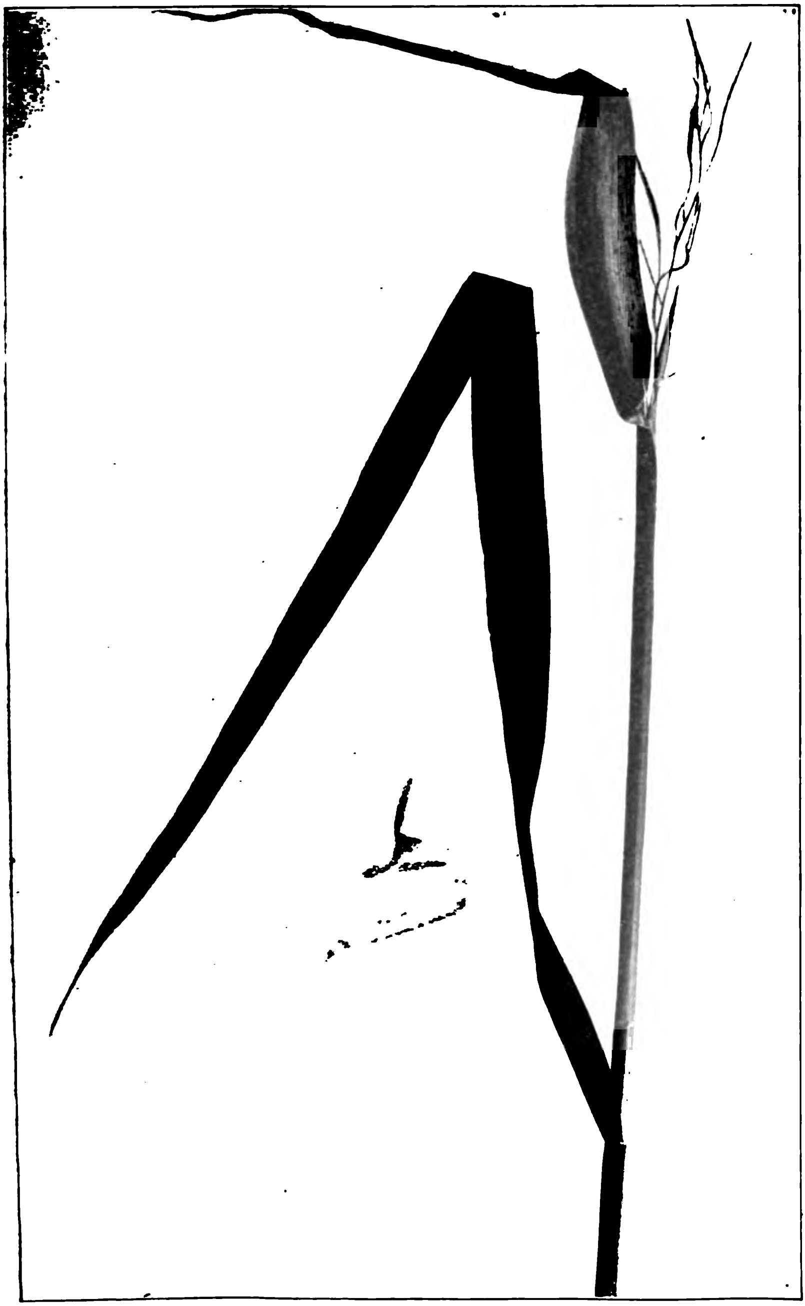

PLATE XIV.

DESCRIPTION OF PLATE XV.

Showing in Fig. 1 the aphis eggs found so common on apple twigs in 1908 and 1909. The writer gathered a number of these twigs (see p. 117) from different sources, and bred out the insects, in an attempt to secure *Macrosiphum granaria* or *Syphocoryne avenae* to learn whether these carried the bacteria of oat blight, to and from the apple. Upon being hatched these aphides failed to live upon the oats at all, even after several generations had been produced upon the apple, indicating that the eggs so plentiful on apple twigs in 1908 and 1909, were undoubtedly those of *Aphis mali*, the apple aphis.

Showing in Fig. 2, the first generation of aphides on the buds several days after hatching from the eggs.

Showing in Fig. 3, later generations of the aphides at work on the apple leaves. The above illustrations are from work carried out in the pathologium. All enlarged two diameters. 3-3-09 and 5-6-09.

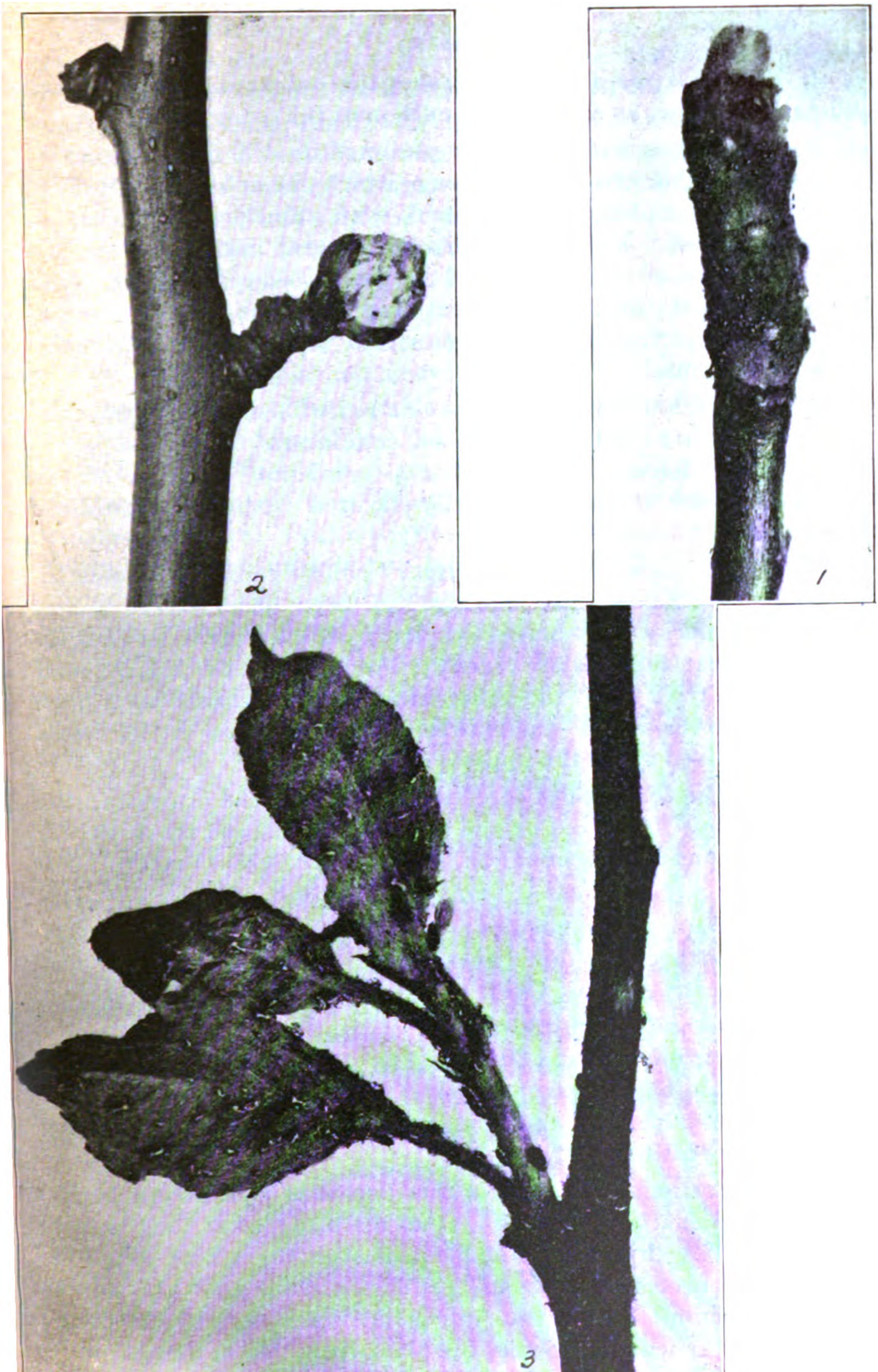

PLATE XV.

SUMMARY.

1. There is prevailing throughout the oat area of the centra and eastern states an abnormal condition of the oat crop.

2. Many reasons have been assigned by different writers a the cause of this condition, among which have been mentioned physiological, resulting from the cold, wet, cloudy seasons; again insects have been held responsible; in several instances a specifi bacterial disease has been assigned as the cause. The difficulty o distinguishing the bacterial blight from other similarly appearing, but more limited troubles, has given rise to much difference of opinion as to the cause.

3. The writer finds that a specific bacterial disease is the chie factor in bringing about this abnormal condition of the oat crop.

4. This disease results from a symbiotic relation of tw bacteria. Their activity is greatly favored by rainy, humid an cloudy weather.

5. The disease in its severity is chiefly confined to oats, although a somewhat similar disease has been observed to a less extent on timothy and bluegrass, and, on each of a susceptible variety of wheat and barley recently brought to the Experiment Station, for trial. In the observations on timothy and bluegrass it is to be noted that the foliage suffers but little, while the culm is killed above the upper joint.

6. The chief method of infection is through the stomata, the organisms being spattered on the leaves from the soil by rains. A secondary means of dissemination is the work of grain insects.

7. In Ohio the seasons of 1907, 1908 and 1909 have been quite favorable to the development and spread of this disease. Probably the greatest outbreak of this disease occurred in 1890, when it was observed from the Atlantic Coast to as far west as Indiana, and from the Great Lakes to the Gulf States.

8. The yields of oats in Ohio in 1890, 1907 and 1908, the three years when this blight was excessive, were reduced respectively, 36.7 percent, 24.3 percent and 14.4 percent below the average for the past eighteen years.

9. The preliminary effects of this disease is a yellowing, beginning either as small, round lesions on the blade, or as long, streak lesions extending throughout the blade or even the whole length of the culm and blades. Occasionally it begins at the tips and works back into the culm; again the upper leaves often break down through a weakened condition of the plant from defoliation below.

10. The ultimate symptoms wherever the disease has made much progress, are partial or general collapse of the leaves, due either to active lesions within the blades, or to a weakened vitality of the plant; this weakness results directly from impairment of foliage, or sickness of culm and roots. In the advanced stages the affected blades take on a mottled to almost red color, which has been called "rust," "blight," and emphasized by the expression "as red as fire."

11. It seems probable that where the soil has become filled with these specific organisms, it has become partially "oatsick." Apparent "oatsick" areas have been observed by the writer and he attributes these conditions to the bacterial blight organisms.

12. Observations indicate that the "blast" of oats is more or less directly proportional in amount to the severity of the blight disease. In some instances "blast" is directly due to active lesions of the blight killing the parts of the panicle infected. As a rule, however, it appears that "blast" results from an impaired vitality, occasioned several weeks previous to the emerging of the panicle. Heads examined one to two weeks previous to the time for their appearance showed "blasted" kernels, and the amount of "blast" was apparently proportional to the amount of blight, or in other words, to the amount of impaired vitality.

13. Some variation in the amount of blight is observed in different areas on every infected field; these irregularities are little influenced by fertility or drainage.

14. The writer has studied the morphological, cultural, physical and biochemical features of these two specific bacteria, and finding they differ from previously described organisms*, they have been named *Pseudomonas avenae* n. sp. and *Bacillus avenae* n. sp.

15. The difficulty met with in diseases which are more or less soil troubles, that is, diseases which may be carried for several years in soil without the presence of their particular hosts, have best been overcome by breeding and selecting resistant strains.

16. From observations gained through artifical inoculations and from conditions as they appear in field crops, and upon the different varieties of oats, it seems to the writer, that there is a good opportunity for selecting resistant strains.

ACKNOWLEDGEMENTS.

The writer desires to express his appreciation to those who have helped in gathering material and data for this publication; to Messrs. Rankin, Behoteguy and Goheen, for their assistance in laboratory and photographic work. The writer is especially indebted to Prof. A. D. Selby for his kindly suggestions and readiness in furthering the investigations.

* The writer reviewed the systematic works of Migula and Chester. See references (23) and (24) in literature cited.

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OHIO Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., NOVEMBER, 1909.

BULLETIN 211

The Bulletins of this Station are sent free to all residents of the State who request them. When a change of address is desired, both the old and the new address should be given. All correspondence should be addressed to *EXPERIMENT STATION, Wooster, Ohio.*

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The Bulletins of this Station are issued at irregular intervals. They are paged consecutively and an index is included with the Annual Report, which constitutes the final number of each yearly volume.

To His Excellency, JUDSON HARMON, *Governor of Ohio:*

SIR: In obedience to the requirements of Section 409-cc, Revised Statutes of Ohio, I herewith transmit a report of investigations on the forest conditions of Ohio, made by the Ohio Agricultural Experiment Station during the year 1909.

Respectfully submitted,

D. L. SAMPSON,

Secretary of the Board of Control.

Negative by W

Remnants of the primeval forest showing original trees of the white oak type

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 211. NOVEMBER, 1909

FOREST CONDITIONS IN OHIO
THIRD ANNUAL REPORT

REPORT OF THE DIRECTOR

JOHN COURTRIGHT, *President of the Board of Control:*

SIR: I have the honor of submitting herewith the third annual ...rt of the Forester of this Station for the year ending November ...909.

Cooperative forest work: The cooperative work in forest ...ement at the Boys' Industrial School at Lancaster is being ...d, and the department is cooperating in the management of ...atural forest belonging to Kenyon College, Gambier; in the ... of forest trees around the sources of water supply at Ober-...the grounds of the State Reformatory at Mansfield, and the ...State Hospital for the treatment of tuberculosis at Mt. Vernon. Advice and directions for the improvement of woodlots have ...en given to a considerable number of land owners. The number ...o are willing to set aside their woodlots to forestry is increasing ... year and there are, at present, 606 who are cooperating with ...Station in tree planting, and 263 who have applied for trees. It ...te frequently happens that those who have asked for trees to ...t on cleared land decide, when their attention is called to the ...tter, that they could do better to devote their woodlots to permanent forestry work than to plant on cleared ground. This feature ...the work is given special attention because the necessity for it is ...apparent.

The forest survey has been very useful in making possible a study of the forest conditions of the state; in learning the attitude of land owners toward forestry; in determining the rate of growth of different species of trees and their adaptability to various soils; in creating an interest in forestry and in helping those interested to make a start in the right direction.

The survey the present season was started in Greene county, near where the work was closed the previous season. Parties desiring trees have been visited, also those wishing to improve their woodlots, and advice has been given as to the best method of procedure. Measurements have been made of trees in planted groves and the general forest conditions noted.

During the latter part of the season the work was carried on in Washington and Athens counties. Considerable attention was given in these counties to a study of the rate of growth and to the effect of deforestation on steep hillsides in permitting erosion and landslides. A very serious condition is found to exist in the form of many eroded hilltops and valleys covered with debris.

An effort has been made to determine the percent of untillable land fit only for forestry, also the comparative amount of so-called forest which is in a productive condition, or gives promise of becoming so. Complete working plans have been made of some large tracts.

More help needed. The department is greatly in need of more trained helpers. But little of the field work can be done except by those trained under conditions which exist in Ohio. The fact that an important part of the good accomplished by the survey consists in the advice given to the owners of farm woodlots is sufficient to show that the survey should be conducted by men experienced in forestry.

Increased nursery facilities are imperative. To propagate all of the species needed for woodlot improvement requires more skill and entails greater expense than to grow catalpa and locust seedlings for grove planting. Besides a great number of trees of all species need to be grown. It is not practicable, for various reasons, to purchase trees, except a few species, hence better facilities for growing them need to be provided.

Demonstration necessary. The plan of furnishing trees to farmers is satisfactory in many respects but does not meet all requirements. There is need of more examples of woodlot improvement. Such illustrative examples should be more permanent in character than can be the case under general arrangements. Such as can be located on county farms and state institutions can serve a

useful purpose, but more are needed than can be located in this way. More and better examples could be secured if it were possible to deal somewhat more liberally with individuals; but if towns, cities or counties were enabled to take hold of the matter the work could be put on a more permanent basis.

Forest parks. To this end an enabling act is needed to permit municipalities and counties to establish forest reserves or forest parks in cooperation with the state. Such parks would serve the double purpose of parks and forests. They would be quite different from the ordinary city parks, costing far less to establish and maintain. If the state were to provide the superintendence of such forest parks the work could be made somewhat experimental in nature and serve as a demonstration as well.

The contact of the Station authorities with the owners of woodlots has shown that demonstration forest plots are greatly needed. The people want to see what can be done in tree culture and in the care of woodlots. They must be convinced by actual examples, and these illustrative examples must be numerous enough so that various methods can be shown. One or two forest parks in each county would be none too many.

Many city people are interested in forestry and such examples would be of great value to them as well as to farmers. The influence for good would constantly grow. The state could, in this way, come into virtual control of considerable forest reserves.

Respectfully submitted,

CHAS. E. THORNE,
Director.

FORESTRY CONDITIONS IN OHIO

REPORT OF THE FORESTER

W. J. GREEN.

A complete forest survey of the state has not been made but the work has progressed far enough to warrant the following conclusions:

1. The quantity of good merchantable timber in the state is very small. Nearly all of the trees which are now being cut and marketed are defective and were formerly rejected when the best timber was taken.

2. To harvest the mature trees which remain, in order to save them before decay has gone too far, is a matter of prudence rather than of reckless waste.

3. Many of the mature trees of our forests are of inferior species and are detrimental to the smaller trees which surround them; in fact they are weed trees and ought to be cut.

4. The most valuable trees of our forests are young trees of various ages. Their value is measured by the growth which they are capable of making. Well stocked young forests are capable of yielding a good rate of interest, even on land worth fifty dollars per acre.

Forest conservation to most people means the saving of mature trees, and nothing more. Real conservation takes into account all that is of value, also that which has a potential value.

Current ideas regarding values of forest products need an entire reconstruction, as upon a proper conception of what constitutes the most essential part of a forest rests the fundamental doctrine of conservation. To save that which is worth but little and to waste that which is full of possibilities shows wrong ideas regarding values, but examples of this kind are very common. Almost every one appreciates the worth of a large oak, walnut or pine tree, but to most people a seedling of the same species is nothing but a weed. It seems hard for any one, who has not studied the rate of growth of trees, to realize that a mature tree makes but little growth and is worth saving only as long as it remains sound, while a thrifty young tree is growing into value at a rapid rate.

A mature tree is an insecure investment and yields a very low rate of interest. Several young growing trees may occupy the same space as one large one, thus dividing the risks, and adding a much greater volume by growth.

The early settlers wisely set aside a portion of each farm as a woodlot, but they had almost no regard for any except the large, mature trees.

The value of saw timber on the farm has never been questioned but the early settlers and succeeding generations have thought of it only in terms of large trees.

Seemingly almost no one has placed any present or future value on small trees. Forest conservation has meant nothing but to save the large trees.

Down to the present time there has been almost no change of sentiment in this matter. The treatment which has been given our forests bears out the truth of this assertion. A change of sentiment in the matter is imperative.

But little will be done in the care of our timber trees until we come to realize that forest conservation means the saving of trees of all ages and sizes. This is not enough. We must learn first of all that the thrifty growing trees make up the most valuable part of the majority of our forests. We need not only to learn the value of young trees but that in giving them the proper care we are creating conditions which are the most favorable for the preservation of the large trees.

It seems to have escaped the attention of the general public, including the majority of land owners, that the most serious forest destruction which is now going on in this state is confined largely to the immature trees. Browsing animals annually kill or maim millions of seedling trees. Reproduction is thus made impossible; forest conditions are destroyed; the large trees die prematurely and the few remaining young trees fail to develop properly.

Comparatively few farmers within the state set any value upon the second-growth forest trees in their woodlots. After the mature trees are gone many owners would destroy the saplings if it were not for the cost of clearing the land. There are more land owners who are desirous of planting trees on cleared land than there are who are willing to save and care for the native forest trees in their woodlots. It is true that the trees in many woodlots are not worth saving and caring for because constant pasturing has prevented reproduction. Of 2,483 woodlots examined in 29 counties of the state about 50 percent are of this class. In some counties practically all of the woodlots have been pastured so long that grass has taken possession of almost the entire surface of the ground. In the majority of such cases it is easier and better to plant trees on tillable ground than to start them in sod, but in other counties there are many woodlots where little or no pasturing has been done and

fair stands of valuable young trees are found. In but few of thes woodlots are these conditions ideal, but the cost of making im provement cuttings and of interplanting is far less than to replan anew. There are considerable numbers of young, growing forest within the state which can be improved and made valuable at a nomi nal expense. In their present condition some of them are not wort keeping, but many are well worth reconstructing.

Such young forests could be made valuable assets within a ver few years, but if nothing is done with them they will soon be be yond the stage of reconstruction. If it were not for lack of bot knowledge and faith on the part of their owners the necessar measures would be taken to put them into productive condition.

If the entire income of the state, for a decade, had been used i the purchase of land and the planting of forest trees we would hav no more acres covered than we now have in second-growth forests

The cost of these forests has been merely nominal and has no been felt. Their value as they stand would run into the millions They offer fine opportunities for the investment of capital in th way of improvement. But they are generally not appreciated; i fact most of them would be destroyed but for the labor required.

The investigations of the Experiment Station show that th improvement of the best of these woodlands is feasible and can b done with profit. A few farmers have become convinced and hav begun the work of improvement but a start has hardly been mad Forest improvement, like the good roads movement, is a matte which concerns the people as a whole. Just how the farmer ma be financially aided to any extent in the work does not appear, bu first of all sentiment must be created and then numerous example of successful treatment of timber tracts must be made. What t do and how to do it varies according to locality and it is the duty c all citizens to favor any means which will multiply illustrative ex amples of forest operations, particularly those which have to d with the protection and improvement of young growing forest Certain citizens whose interest and zeal are undoubted can b encouraged and helped to do forestry work of a more or less pe manent character. Some very excellent work can be done in thi manner, and such work is now in progress on a number of farm where the owners are cooperating with the Experiment Statio The present plan does not admit of putting the work on a sufficien ly permanent basis, however.

COOPERATION WITH PUBLIC INSTITUTIONS

There are four state, one county, one municipal, two educational and two charitable institutions now cooperating with the Station in forestry work. Nurseries have been established at three of these institutions. Work of this kind is enhanced in value because of its permanency. Other institutions desire to take up such work and it is the policy of the Station to carry on as much of it as means will permit, 85,891 trees have been furnished for this purpose and about 290,000 seedlings have been grown at these institutions, some of which are now in the seed beds.

The Station is authorized by law to test the value of various species of trees for ornamental planting. Wherever forestry work is done by the Station at any institution and a nursery established, trees for ornamental planting can be included.

Not only can a considerable saving to the institution be effected in this manner but the Station can, from time to time, make notes on the value of these trees for landscape work, thus extending the scope of the operations already in progress on the Station farm.

FOREST CONSERVATION CONCERNS THE CITY AS WELL AS THE FARM.

Many dwellers in towns and cities feel great interest in forestry and would be glad to give active aid to the cause. Some are doing so by the improvement of forest lands which they own, but there are greater numbers who are not able to do this but who greatly desire to enjoy the forests and to help along any movement tending to their improvement. The preservation of the forests for natural scenery; to check winds and hold back the waters; to harbor birds and animals; to produce materials for building and manufacturing are matters which concern city people as well as those who dwell on farms.

The obligation to protect the forests rests upon all and the opportunity to enjoy them should be enjoyed by all. Cities should own forest parks in which the design should be to get away from the conventional and costly style of landscape gardening now so common in city parks.

Such parks, if made as natural as possible, would cost far less to establish and maintain than city parks and would serve many purposes. They would help to arouse an interest in forestry and to show its practicability. They would afford means of recreation and study, supplementing the courses in school. If the Station

were enabled to cooperate in the establishment and maintenance of such forest parks the arrangement would be mutually helpful, since the work would be started along forestry rather than ornamental lines and its permanency would be reasonably sure.

THE INTEREST IN FORESTRY IS INCREASING.

It does not seem advisable at present to discontinue cooperative tree planting with farmers, but the interest in this phase of forestry is such that there is less need of fostering it than was the case a few years ago. The chief work which now needs to be done on the farm, as above stated, is to encourage the care of woodlots.

It is gratifying to note that the interest in forestry within the state is constantly growing and that the number of trees planted each year is increasing.

Catalpa and locust are the species which have been planted more than any others. These are valuable for certain purposes but our best native trees ought not to be neglected, as seems likely that they will be unless more interest can be awakened in woodlot improvement. A considerable change in sentiment is apparent however. As showing, to some extent, the awakened interest in various phases of forestry, it may be stated that during the winter and spring months of 1909 the average number of letters per month sent out by the department was 223, the total for the year amounting to 1,472. More than 50 lectures were delivered and about 300 visits made to those who desired help in forestry work.

The shaded area indicates the counties wholly or partially covered in the reconnaissance survey

A—represents the number of cooperative plots
B—represents the number of woodlots examined
C—represents number of acres in woodlots examined for each county

Clermont County	Warren County	Greene County
A— 10	A— 7	A— 17
B— 7	B— 7	B— 17
C—148	C— 148	C— 502
Brown County	**Highland County**	**Athens County**
A— 7	A— 11	A— 5
B— 8	B— 5	B— 3
C—148	C— 127	C—5095
Meigs County	**Washington County**	**Wayne County**
A— 6	A— 14	A— 11
B— 15	B— 62	B— 106
C—536	C—1450	C—1790

A RECONNAISSANCE FOREST SURVEY

BY EDMUND SECREST

Continuing the policy of making a reconnaisance survey of the forest resources of the state, initiated in 1907, the Station has during the past season been conducting a research into the forest conditions of a portion of the state, with a view as heretofore to determining the existing conditions of the native forest lands, and for the purpose of studying the various artificial plantations, established by land owners in cooperation with the Station.

Special attention was given to the study of the native woodlots, and to the making of plans of operation for those interested and wishing state aid. Preliminary steps toward making working plans were taken in the case of several large tracts. By another year data of this nature will be available for publication.

TERRITORY COVERED

The initial work begun and territory wholly or partially covered by the survey includes the counties of Wayne, Greene, Highland, Warren, Clermont, Washington and Athens. Aside from this territory numerous parties living in adjacent counties were seen upon request for the purpose of woodlot examinations.

WAYNE COUNTY

Geographically, Wayne county is situated in northeastern Ohio, in the heart of one of the excellent agricultural areas of the state.

It is situated very near the dividing line between the waters of the Lake and the Ohio River and upon the northern margin of the coal regions. Two deep preglacial channels traverse the county. One of these enters Milton township from the north, divides into two branches, one of which extends southeastwardly along the valley of Chippewa creek into Baughman township, where it expands into a broad swamp, which was doubtless the site of a prehistoric lake. The other branch from this channel extends southward, passing east of Wooster and forming the valleys occupied by the two branches of Applecreek, leaving the county at Fredricksburg. The second main channel forms the valley now occupied by Killbuck creek. It enters the county near the east half of Congress township and extends on south through the county, a branch leaving it at Millbrook which passes out at the southwest corner of the county.

In places these channels expand into fertile alluvial plains; in others, they are of a swamp-like nature indicating location of prehistoric shallow lakes. There are no high hills in the county nor very abrupt topographical features. Gently rolling hills form the surface features in general, and these are greatly modified in many places by deep deposits of drift clay. Throughout the county there is a series of glacial lakes, taking for their sites the old prehistoric channels previously mentioned. These lakes are gradually being filled by silt from the hillside wash.

In a recent soil survey by the U. S. Department of Agriculture the soils of a large part of Wayne county were described and classified. The four important types which will receive mention here are the Volusia silt loam, the Miami clay loam, the Yazoo clay and the Peat. The area of the last two is restricted and confined mostly to the proximity of the glacial lakes, marshes and swamps. These classifications are closely associated with forest types. A small part of the townships of Canaan, Milton, Greene and Franklin, and practically all of Chippewa, Baughman, Sugar creek, Paint, East Union and Salt Creek are included in the carboniferous or coal zone. The other portions of the county are of Waverly formation.

The soils are the result of glacial drift, modified by the Waverly shales and sandstones. The principal streams are Killbuck creek on the west and Chippewa and Sugar creeks in the eastern part of the county.

CLASSIFICATION OF AREAS

Each distinct soil type previously mentioned is represented by a peculiarity of forest growth. Three distinct types are easily recognizable and the line of demarcation is often quite sharply defined. These types are as follows:

1. The White Oak type
2. The Beech-Maple type
3. The Swamp type

In certain sections of the county types Nos. 1 and 2 lose their distinctive characteristics and become more or less fused. This is particularly true through parts of Chippewa and Baughman townships.

The white oak type is characterized by a once luxuriant primeval forest of white oak, having for its underwood a dense growth of dogwood. Upon the removal of the large white oaks there sprang up a growth of black and scarlet oaks with a slight admixture of white and red oak and maple. The latter frequently associates with dogwood in the formation of the ground cover. There is, of course, an occasional admixture of other species, as beech, ash

black gum, pignut, mockernut and shellbark hickories, and chestn but they have no significance so far as affecting the character of t forest type is concerned. This particular type is associated wi the Volusia silt loam and covers generally the southern and sou western portion of the county. While the white oak forest forme covered this area, the age of its preponderance is passed. Its eli ination from the struggle is due to two causes.

First, The uncertainty of the white oak acorn to germinate, its propensity to germinate in the fall after dropping.

Second, Rapidity of growth. The black oak generally gr one-third more rapidly than the white oak. Thus in many plac the white oak is suppressed, and in many places finally crowded c by the faster growing black oak. Hence we find the original stan of white oak replaced by the black oak.

Photo by Secr

A characteristic Wayne county woodlot in an unpastured condition showing the margin along the southwest side devoid of undergrowth and reproduction. The wind sweeps the leaves off and a growth of grass results thereby destroying favorable conditions for reproduction.

One of the characteristic arborescent features of this type is t undergrowth of dogwood. When all destructive agencies are eli inated from the woodlot it most frequently takes complete poss sion, even to the exclusion of all other growth.

The following tables indicate the reversion of the growth in the white oak woodlot.

AVERAGE REPRODUCTION OF AN AREA 25 FEET SQUARE

Species	Number seedlings
Red Maple	480
Dogwood	55
Black Oak	35
Cherry	20
Ironwood	11
White Oak	12
Pignut Hickory	4
Chestnut	4

In this case the more inferior species have almost taken possession. The following data represent the type of woodlot seeded to white ash:

REPRODUCTION OF AN AREA 25 FEET SQUARE WHERE WHITE ASH PREPONDERATES

Species	Number seedlings
White Ash	176
Mockernut Hickory	5
Dogwood	4
Red Maple	3
Black Cherry	3
Ironwood	1
Black Oak	1
Red Oak	1

The woodlot from which these data were taken is a splendid example of the unpastured woodlot of this type when ash seed trees are present, and when the dogwood and ironwood have not had previous possession.

Occasionally the white oak does reproduce and that usually in small groups of extremely dense stands. Considerable light, and a plentiful supply of leaf mulch and moisture, seem to be the conditions required.

THE BEECH-MAPLE TYPE

The predominating trees are the beech *Fagus Americana*, and the sugar maple *Acer saccharum*; associated with these species, may be found in varying numbers, tulip poplar *white wood*, *Liriodendron tulipifera*, red maple *Acer rubrum*, black cherry *Prunus serotina*, white ash *Fraxinus Americana*, ironwood *Ostrya Virginiana*, blue or water beech *Carpinus Caroliniana*, shellbark hickory *Hicoria ovata*, mockernut hickory *Hicoria alba*, cucumber tree *Magnolia acuminata*, and occasionally chestnut *Castanea dentata*.

Photo by Sears

Catalpa planted in an open space in the woods. 3 years growth

The soil of this type is a clay loam, and is classified by the U. S. Bureau of Soils as the Miami clay loam. Where conditions are favorable for regeneration sugar maple usually preponderates. Occasionally the weed ironwood takes complete possession, to the exclusion of other species. White oak also frequently reproduces quite freely and is usually found in mixtures in a greater or less degree.

REPRODUCTION IN THE BEECH-MAPLE TYPE, AREA 20 FEET SQUARE

Species	Number Seedlings
Sugar Maple	101
White Ash	99
Black Cherry	10
Black Oak	9

There is an absence of weed trees in the above plot, because of the absence of "seed trees" of that species. This area is a splendid type of the unpastured woodlot.

THE SWAMP TYPE

This type is confined to the glacial lakes, swamps and marshes and the larger creeks, where drainage has been restricted. The principal species found are the silver maple *Acer saccharinum*, black ash *Fraxinus nigra*, swamp white oak *Quercus platinoides*, pin oak *Quercus palustris*, burr oak *Quercus macrocarpa*, white elm *Ulmus Americana*, and occasionally the tamarack *Larix Americana*. When ash is found it usually preponderates, likewise the tamarack. The latter is found in the northeastern part of the county near Fox Lake in considerable quantity. The pin oak occurs in dense pure stands in many parts of the Killbuck Valley.

WOODLOT CONDITIONS

Five hundred and forty-nine woodlots in this county were examined in the course of the survey, and detailed reports were made upon one hundred and twelve. Eighteen percent of these woodlots were in fairly good condition as a result of not being pastured by livestock and having sufficient young growth for regeneration. Forty-nine percent were pastured, but either contain sufficient young growth to restock the area or are in such condition that they can be reconstructed. The remaining thirty-three percent constitute the woodland pasture containing an under-normal stand of either matured trees or culls and having no young growth. The ground is covered with a heavy sod and reconstruction by natural means is impractical and many times impossible.

According to the official statistics there are 298,406 acres of l in Wayne county, 35,114 acres of which are in woodland.

No large bodies of forest exist, but the woodland is cut up i areas of approximately 16 acres each. There are comparatively purely second-growth woodlots in the county. The most comn type found is the woodland pasture. Again there occurs qu frequently the remnants of the virgin forest in an unpastured st The "remnants" in this case may be trees matured but still in g state of preservation, or they may be culls which were left for w of utilization. The young second growth has sprung up where spaces are created.

Negative by

Large maple overtopping saplings of shellbark hickory

THE WOODLAND PASTURE

Wayne County contains more profitable farm woodlots than other strictly agricultural county in the state. There still rem many thousand feet of oak, chestnut, beech and maple fit for saw. It must be said, however, on the whole, that poor forest ditions exist. Regeneration does not occur as it should, due numerous reasons. As elsewhere in Ohio, the potent factor in encing the regeneration of the woodlot is the pasturing of the fo by live stock. Practically 80 percent of the standing woodlots thus abused. It is true that this pernicious habit has apparently direct influence on the forest growth—it does not affect the matu or nearly matured trees, but in the management of a woodlot

future growth the strict exclusion of live stock must be enforced for all time to come. Were the losses incident to this practice generally known it would be largely discontinued. A woodlot is pastured not because of the nourishment derived but for the sake of the shade, and because the resulting evils are not recognized. The fact that the effects of grazing are insidious is one of the gravest dangers confronting the perpetuation of the woodlot. With the passing of the existing growth the woodlot ceases to exist, because there are no young trees, or they are of such species and quality that they possess no value.

The average value of the woods pasture, as given by owners, does not exceed 21 3-5 cents per acre per annum, while that of a properly stocked unpastured woodlot under favorable conditions and without any system of management will pay at least two dollars per acre per annum and usually more in the wood product it yields.

THE UNPASTURED WOODLOT

About eighteen percent of the timber area in Wayne County is in a fair sylvicultural condition as a result of live stock exclusion. These areas have been under no system of management, but are merely the results of nature's endeavor to propagate her kind. Where conditions have been favorable considerable young growth of value may be found. In others nothing but worthless underbrush remains to succeed the present growth.

The two types of forest figure prominently in the regeneration of woodlots. Generally speaking, the beech-maple type reproduces more freely and under more adverse conditions than the white oak type, unless the latter contains ash. When this is the case that species is inclined to reproduce freely, assuming of course that the trees are good seed bearers. Throughout the southern part of the county this condition is unfortunately not frequently met with. The great majority are reproducing to the common flowering dogwood, which in many cases has taken entire possession of a woodlot, excluding any other valuable species which might otherwise take possession. No doubt the dogwood, when the stand is not too dense, often aids the ash and other species in establishing themselves but such does not seem to be the case in this county, where the dogwood grows in remarkably dense stands.

The beech-maple type on the other hand reproduces to ironwood, maple, ash, and occasionally tulip poplar. While the type is characterized by large specimens of beech there is usually little reproduction of that species. Its production of seed is uncertain. Sugar maple and ironwood constitute the prevailing reproduction.

IMPROVEMENT OF WHITE OAK WOODLOT

The woodlot owned by Mr. S. S. Taggart, lying four mi south of Wooster, is a representative type of the oak woodlot, c taining white ash reproduction. It is obvious that this species v figure more prominently in the regeneration of woodlots than a other native tree.

The growth may be described as mixed, both as regards spec and size. There are a few large trees of the virgin stand remainin with considerable large second-growth individuals of black a scarlet oaks, shellbark and pignut hickory, black cherry and che nut. The oaks preponderate. There are also a few matur individuals of black gum, ironwood, blue beech and dogwood.

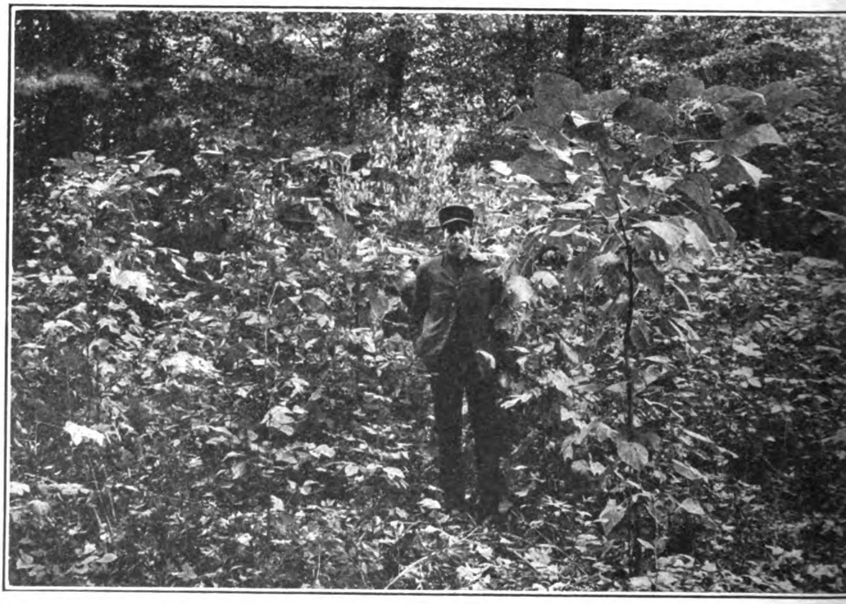


Photo by Secre

Tulip poplar and catalpa growing in a woods, after live stock was excluded. The catalpa were planted

In parts of this woodlot there is an excellent stand of secon growth white ash, ranging in height from four to twelve feet. Th growth is overtopped by large white and black oaks. These latt trees are high headed and for the most part do not seriously sha or suppress the young ash.

Along the west side of this woodlot is a strip of land runni inland about one hundred feet which is entirely devoid of any you growth. In fact nothing but large, limby and matured trees for

the stand, the growing value of which is practically nil. The ground cover consists of grass, which has encroached upon the area as a result of the constant sweeping of winds, and the consequent removal of the litter. Thus conditions for natural regeneration are destroyed and the encroachment is constantly extending inward.

Another portion of this woodlot contains a dense stand of older and larger trees and less young growth. The ironwood exists in considerable quantity, being seeded from a very few matured seed trees. A number of white ash seedlings are interspersed among the ironwood, but the latter preponderates. With the exception of the strip along the west side of the woodlot the leaf mulch is well preserved and hence conditions for germination of seed are good.

PLANS FOR IMPROVEMENT

Before attempting operations in a woodlot of this kind one should have in mind a definite plan or ideal condition. A fundamental consideration would be the needs which the timber must supply. The initial operations on the above described woodlot would be the removal of the weed trees. This class includes the ironwood, the black gum and in some cases the dogwood. The ironwood is a prolific seeder and in this woodlot as well as many others of its type has taken entire possession of areas which might otherwise have been occupied by the ash. In some cases a certain amount of ironwood seeding is beneficial to a woodlot, as it is an excellent species to preserve a ground cover and leaf mulch, but where too dense it is detrimental. The safest plan is to remove the seed trees as soon as possible. The next operation would be the removal of the matured trees—those which are marketable. This operation will remove the large white oaks which are standing in the open strip which is on the west boundary of the lot. Those trees which are suppressing the young ash unless of special value should also go. The space created in the interior of the woodlot by the removal of the large trees will doubtless be seeded naturally to ash, which would be an economical means of securing a stand of this valuable species. Or if post timbers are desired the locust, catalpa or osage orange could be interplanted in these places. The strip along the west side of the lot approximately one hundred feet wide could be planted in a number of ways. The outer row of trees, however, should be evergreens. White pine or Norway spruce would be best suited for this purpose. Considerable advantage could be secured by planting the first row or two on the west side to Norway spruce and four or five rows on the inner side to white pine. The trees may be put in eight or ten foot rows and the same distance apart in the rows. The spruce is

more rigid and better able to withstand the force of the wind tha the white pine, hence it is an excellent tree for the outer row. Th rate of growth of the two species is approximately the same. Th areas inside the evergreen belt may be planted either to locus catalpa or osage orange. In this case the locust is better suited t the soil conditions. It could be planted in rows ten feet apart, wit the trees five feet apart in the row. The sod where the pine an locust are to be planted should be broken if possible. A bull tongu plow would be a good implement for this purpose.

IMPROVEMENT OF THE BEECH-MAPLE WOODLOT

A good representation of this type is the woodlot owned by Mı J. E. Snyder, located one and one-half miles south of Burbank, i Canaan Township.

CHARACTER OF GROWTH

The growth is mixed, both as regards size and species, wit sugar maple preponderating. Aside from this white ash, red an white oak, beech, mockernut hickory, ironwood, white elm and blac cherry form the species. There is considerable reproduction o sugar maple, white ash and ironwood.

The second growth and matured trees combined form a fairl normal stand. There are a number of small openings fairly wel stocked with reproduction of ash, maple, elm and ironwood.

Another portion of this woodlot is practically of the same com position, having possibly more matured beech, but has been graze for many years. No reproduction or second-growth of any descrip tion exists, and the ground cover is grass.

On the west of the woodlot is a ravine running the entire length The ground is quite densely shaded by large beech and maple and i entirely bare of any grass or ground cover.

PLANS FOR IMPROVEMENT

This woodlot is primarily desired for the revenue it yields in th production of maple syrup. It is also very favorably situated fo windbreak utility, and aside from these important features th owner desires wood products and wishes to maintain it for thes reasons.

The first and fundamental principle for improvement is the ex clusion of live stock; without this nothing can be accomplished. Th removal of the ironwood and beech should be the next consideration The former has seeded considerable area to no advantage, and ther yet remain spots which are in need of reproduction. A thinning o large beech and maple along the slopes of the ravine should be made so that sufficient light may enter to encourage reproduction of th

maple, which would immediately take place here. The removal of the beech from the entire woodlot should be accomplished in time, although a clear cutting of that species should not be attempted. It would be better to remove them slowly in order that they may protect the tall and shallow rooted maples from the force of high winds which have been such a potent factor in the destruction of maple groves during recent years. In order to promote the longevity of the large sugar maple the ground should be protected by a mulch, the preservation of which is due to a growth of under brush. Therefore this growth should be encouraged as much as possible and it is desirable that it be a growth of some value which will ultimately replace the older trees.

A vacant space or two exists where the soil is fertile and catalpa might be planted at a distance of six or eight feet apart each way.

Locust can be planted on each side of the ravine, after a part of the beeches are removed. The locust can be planted six feet apart each way, and plowing or cultivation in this case would not be practical.

The pastured portion of the woodlot is not worth reconstructing, owing to the absence of young growth and the almost hopeless condition of the ground cover. Natural regeneration of desired species would not occur and the existing growth is matured and of inferior species.

GREENE COUNTY

LOCATION AND TOPOGRAPHY

Greene County is located in the heart of the great agricultural belt of Ohio. There is practically no waste land resulting from topographical conditions. The eastern portion of the county is level, verging into rolling in the north portion. A part of the north townships is traversed by the deep and comparatively narrow gorge of the Little Miami, which forms an excellent example of geological erosion. This gorge is not over a few miles in extent, but is a striking topographical feature of that section. It is cut through ledges of the Niagara group of limestone, and finally broadens out into a narrow river valley.

The Little Miami River, which traverses the northern and western portions of the county, and its tributaries, Massie's creek and Caesar's creek, are the chief sources of drainage. The comparatively broad valley of the Miami in the western part of the county was doubtless opened out by glacial erosion.

SOIL

The whole county is overlaid with deposits of the glacial drift. A considerable portion of the eastern area is covered with yellow clay, passing into white and black clay according to location.

The lowlands and river bottoms, which consist of the flood plains of the present rivers, are composed of gravel overlaid with clay, loams or very frequently a loess like deposit of which land and fresh water shells make a notable element. This type is characterized by sugar maple *Acer saccharum* and black walnut *Juglans nigra*) which grow to immense size. For fertility these bottoms are unsurpassed.

Photo by Secrest

White Pine planted in an open woodlot, Greene County

WOODLOT EXAMINATIONS

During the course of the survey of this county 315 woodlots were examined and detailed reports made upon 40. Of the total number examined eight percent were unpastured and in fairly good condition. They contained sufficient young trees of value to succeed the mature growth and to form a normal stand. Twenty-eight percent were grazed to some extent; but by the strict exclusion of live stock could be saved and reconstructed. Sixty-four percent of

the total number examined were mere woodland pastures containing no young growth. The growing value of the trees is practically nothing. The ground cover is a heavy sod and the conditions for their reproduction are hopeless. Such areas will soon cease to exist.

The forest tracts of Greene County consist of irregular, detached bodies of woodland, the majority of which are remnants of the virgin forest, and woodland pastures. The former are few and the latter comparatively many. It would not seem strange that forest tracts of any size do not exist in Greene County, where the land is of the best for agriculture and is valued at $100.00 per acre and upward. This must be expected, and will of necessity exist. Yet there are thousands of acres of so-called timberland which is by no means forest land. These areas classed as woodland pasture do not yield in the way of pasturage anything near what they are capable of doing and the amount of wood production is practically nil. If the pasture is the utility desired, it is a utility very much abused, for almost in all cases the trees are formidable barriers affecting the grass growth and its nutritive value. On the other hand, under the system of intensive pasturing the woodlot has no growing value; those trees which now stand are fast declining, owing to the absence of the protective undergrowth and reproduction. As a barrier to wind they are becoming more useless each year, and after each storm many woodlots tell the sad tale of their neglect and decline in the many fallen trees.

Forestry in Greene County, acre for acre, cannot compete with agriculture, but the products it yields for farm use and its almost priceless value as a windbreak, warrant the setting aside of a certain area on every farm for woodlot purposes.

WOODLOT CONDITIONS

TYPES

There are only two types of forest distinguishable and they are not absolute.

The Oak Type, in which the white oak, black, scarlet and red oak occur in mixtures in a greater or less degree with white ash, mockernut and shellbark hickories, red and white elm, red maple, sassafras, black cherry, dogwood, ironwood and mulberry; the young growth is usually ash, maple, ironwood, sassafras and blue beech.

The River Type, being most prominent in the valley and flood plains of the Little Miami River. The large sugar maple and black walnut and white elm are characteristic species, which originally occupied these areas. Occasionally the cottonwood occurs.

The eastern portion of the county contains little besides th woodland pasture. These areas consist of large matured trees, i many cases culls rejected by lumbermen and left standing for wan of use. These trees have dead tops which present a stag heade appearance and give evidence of their rapid decline. The groun cover is grass; a condition which, combined with severe grazing makes regeneration impossible. In many pastured woodlands ther are sufficient ash seed trees to restock the area, where conditions fo germination and growth are favorable.

Negative by Stonsler

A pastured woodlot in Washington county

THE UNPASTURED WOODLOT

While these areas are few, they give evidence of what might be expected under somewhat favorable conditions. Where white ash seed trees are present in a woodlot of this type, that species is one of the first to regenerate, and it is largely upon this feature that the natural future regeneration of these woodlots must depend.

THE BAKER WOODLOT

This woodlot, consisting of about fifteen acres, situated about three miles south of Cedarville, in Ross Township, is probably the best representative of this type found. It was at one time severely culled, but live stock had been excluded for many years, and it is now in good condition. The species found are the white ash, shellbark hickory, white, red, shingle, burr, black and swamp oak, white and red elm, red and sugar maple, sassafras, basswood, black walnut, ironwood, blue beech, dogwood, and black cherry. The matured or culled trees comprise mostly the oak, ash and hickory.

With the exception of about five percent the area is normally stocked with reproduction and second growth. The composition of the stand is shown in the following table:

COMPOSITION OF STAND ON ONE-FOURTH ACRE PLOT

Species	Number seedlings
White ash	154
Shellbark hickory	35
Swamp white oak	14
Red maple	7
Honey locust	4
Shingle oak	3
Basswood	2
Sassafras	2
White elm	1
Red oak	1

The trees ranged in size from one to six inches in diameter. It will be noticed that there is a conspicuous absence of weed trees which is so frequently found in a woodlot of this type.

PLANS FOR IMPROVEMENT

The first thing to consider here is the removal of the large cull trees; although in this particular case they are high headed and do not seem to be doing serious damage to young growth. Yet they are mature and should be marketed. Their removal will create very small spaces. The removal of all ironwood, blue beech and sassafras seed trees should be accomplished as soon as possible thereafter, to prevent any seeding of the open spaces by these species. A few inferior mature ash trees should be left standing to reseed when necessary.

The utmost care should be taken in logging the area. The growth is so dense that careless felling of trees and skidding and transporting of logs would do material damage to the young growth and perhaps ruin considerable of it. Lumbering operations would

best be carried on in the fall or winter and not in the spring when the twigs of the young trees are succulent and easily damaged. Aside from the operations mentioned, and the strict reserve from grazing purposes, very little can be done to better the conditions.

THE WHITELAW REID WOODLOT

LOCATION AND AREA

This woodlot is located in Cedarville Township, about two miles north of the village of Cedarville. It consists of about thirty-five acres.

DESCRIPTION OF GROWTH

The woodlot consists of a mixed growth. There are on an average about twelve large matured trees per acre. Scattered among these trees is second growth of many sizes ranging from seedlings a foot high to trees eight or ten inches in diameter and sixty feet high. The area is not normally stocked. The young growth is grouped to a large extent and there are many spaces which could be in trees. Approximately twenty-five years ago the owner excluded live stock and planted a number of white pine, Scotch pine and sugar maple in open places among the now mature trees. On one side of the woodlot there are four groves, respectively of black locust, catalpa, black cherry and Scotch pine. While the soil is not evidently adapted to the growth of the white pine, it has thrived fairly well under the adverse conditions. On the slopes of a ravine which traverses the woodlot they have attained their best growth. While the trees have splendid form they have in but few cases been planted densely enough, nor have they had enough other trees about them to aid in proper pruning. Some of the pines are dead, apparently from blight, the cause of which is not known. The sugar maples are apparently well adapted although not native to the woodlot. They have outgrown the white pine.

AVERAGE GROWTH OF WHITE PINE AND SUGAR MAPLE UNDER SIMILAR CONDITIONS IN REID WOODS

	White Pine	Sugar Maple
Diameter 4½ feet from ground	5.1 inches	5.6 inches
Height	28 feet	38 feet

The black cherry, probably the only planted grove in the state, has not done as well as might be expected. Its growth has been slow, and the trees as they stand are not thrifty. The catalpas are a mixture of the two species, there being both the bignonioides and the speciosa. Close planting with lack of thinning has somewhat

injured their development. The Scotch pine are the most thrifty of the planted groves. They lack, however, the erectness of form so characteristic of the white pine, but are without doubt more hardy and better adapted to the conditions of the soil.

SUGGESTIONS FOR FURTHER IMPROVEMENT

On the whole the planting thus far has been encouraging. Some changes in the selection of species would be advisable. It would probably be better to substitute the Austrian pine for the White, as the former species tolerates the heavier soil and the limestone formation better than the latter. The Scotch pine appears to thrive, but its habit of growth lowers the quality of its lumber. The sugar maple has thrived as well as could be expected for that species. The reproduction and second growth as it now stands is considerably grouped. The spaces should be planted.

Negative by Sponsler

A three year old locust grove, Washington county

There are but few weed trees to be found, but a considerable number of matured trees should be removed. They are in a number of instances injuring the young growth, besides constantly deteriorating in value. It is of considerable importance that they be removed before planting is done and while there are yet vacant spaces for operations of felling and skidding.

THE CATALPA

Greene County ranks among the first in the number of catal groves established. This species has become popular on account its adaptability for farm purposes and its comparatively rap growth. Many of the groves have been established for windbreak the needs of which are becoming generally manifest.

Considerable difficulty is yet experienced in securing the Catal speciosa true to name. Much spurious seed and many seedlin trees are sold under the name of speciosa, which after several yea growth prove to be either the common catalpa (bignonioides) or hybrid of the same. A study of this species was made this summ and a detailed report will be issued by the Station during t current year.

THE OSAGE ORANGE

Several groves of this species were found in the county. T largest and oldest is probably that in the possession of Mr. O. Bradfute, of Cedarville Township. The trees are of ten year growth and were planted at a distance of 2x4 feet. The soil up which they are growing is a fertile clay loam; while the distance planting is probably too close, they have, nevertheless, ma excellent height growth and are free from limbs. It would ha been better had thinning been done three or four years earlie utilizing the thinnings for poles and stays. The matter of thinni at the present time is of course a problem. Too copious thinni would be detrimental.

In this case, where the rows are four feet apart and the tre two feet apart in the row, it would be better to remove every oth row and every other tree in the rows left standing. This will op the crown cover to some extent, but it will be but a few years befo it will close again. Over prunning would allow too much light enter, inducing the growth of a grassy ground cover. In a fe more years another thinning can be made, the degree of whi would be determined by a number of conditions.

This indicates the possibilities in the growing of this speci and on account of the value as a post timber it would be profitab to plant on many farms in this county.

WASHINGTON COUNTY

LOCATION AND TOPOGRAPHY

Washington County lies in the southeastern part of Ohio, a borders on the Ohio river. It lies wholly within the great co measures, and altogether outside of the drift area. The topograp of the county is greatly diversified. The Ohio river flows from 3

to 400 feet below the tops of the hills which border it and from 500 to 600 feet below the highlands of the interior of the county. The principal streams of the county are the Muskingum, Little Muskingum and Hocking rivers and Duck creek, which have their sources on the highlands to the north. The branches of these streams form a network of narrow valleys which render all of the surface rolling and in some instances when the declivities are abrupt, it may be called broken.

SOILS

The soils are of four main types: 1. Alluvial, 2. Red clay, 3. Sandy clay loam, 4. Gray shaly clay.

The alluvial soils are along the larger streams and cover the flood plains and the valleys.

The Red clays are residual, resulting from the decay of the red, green and blue shales, the latter changing to red through a process of oxidation. This type is of wide extent and is rich in fertility, although heavy and impervious and difficult to till excepting under the most favorable conditions. It is subject to rapid erosion and on it are found many gullied surfaces.

The Sandy clay loam is the typical sandstone soil. As a rule it is of only moderate depth. It is porous and easily tilled, but usually lacks fertility. It is generally characterized by a growth of white and chestnut oak and pignut hickory. It occurs most frequently on the hill tops.

The Gray shaly loam is a decomposition product of green and gray shales. It is usually deep and fertile. It erodes easily, but not as badly as the red clay. This soil is often covered over on the slopes by the red clay, owing to the greater mobility of the latter.

FOREST TYPES

The forest types of this county have not the definite characteristic features, nor the sharp lines of demarcation which are found in mountainous countries. There are, however, distinctive features which may be classified into types. The following classifications will be used:

Creek Bank Type
Upland Type
Old Field Type
Lower Slope Type
Pine Type

CREEK BANK TYPE

This growth follows the creeks and rivers, from the water to the first bench. It is characterized by an abundance of buckeye, butternut, sycamore, red elm, tulip poplar, red oak and basswood.

It consists almost wholly of second growth. The scattered tul poplars and red oaks are the only valuable trees. The buttern does not appear to reach merchantable size on the characterist shallow soil of this type.

It is unfortunate that these areas have a poor composition, f the forest conditions are unusually good, and the proper selecti of trees would ultimately mean a splendid forest.

Negative by Spo

Shortleaf and pitch pine, Washington county

PLANS FOR IMPROVEMENT

In many cases these areas contain seed trees of tulip poplar a red oak, but the reproduction has little chance to survive, owing the presence of buckeye and butternut, and in some cases bl beech. Hence it is important to remove or at least thin out the latter species. In some instances the red oak and tulip poplar a lacking entirely and the growth is made up of buckeye, elm a butternut. In this case it would be better to make a clean cutti and plant the areas to some species well adapted. Tulip popla black walnut or red oak could be used for this purpose. If the t

former species are used it might be a good plan to plant sugar maple in mixture with them. This would help to preserve forest conditions, which a pure planting of poplar and walnut would not supply, owing to their light foliage, and hence inability to shade the ground. The maple possesses this quality to a marked degree, on account of its heavy foliage and consequent shade tolerance. In many instances there are sufficient maple seed trees of either the sugar or red maple to reseed the area for the purpose mentioned.

LOWER SLOPE TYPE

This was originally a white oak and tulip poplar type, with red and sugar maple as an underwood. The tulip poplar has disappeared except for an occasional tree. The white oak likewise is fast disappearing, leaving the beech with scattering seed trees. The percentage of species in mixture may be said to be approximately:

Beech	70%
Sugar and red maple	15%
Red oak	6%
Scarlet oak	5%
Sassafras and butternut	4%

In Independence township the chestnut and sourwood occur frequently in mixture. They are, however, restricted to the east side of the Muskingum river. Where the beech predominates the stand is usually broken and admits the second growth sugar and red maple, red and white oak. Where the beech has been cut clear the stand is more variable and is chiefly coppice white oak, beech, red and black oak, black gum, red and sugar maple. In places the growth of sassafras has become serious. The ironwood frequently appears, but in few places is it present in sufficient quantities to affect the condition of the forest. While the area of this type is not large, yet its future is of considerable importance, because of the possibilities in the way of growth. Practically all of the species which will figure permanently in the future forest are now or at one time have been growing on these areas. Moreover, for topographical reasons they cannot be utilized for agricultural purposes. The forest conditions in most cases are good. The sheltered position and density of canopy have retained moisture and favored humus. The absence of grass, caused by the dense crown cover, has discouraged pasturing, hence danger from this source is not likely.

Negative by Sponsler

A stand of thrifty second growth tulip poplar

PLANS FOR IMPROVEMENT

The first consideration in attempting to improve the woodlots of this type would be the encouragement of those trees found native at one time, but which are being superseded by the more prolific and undesirable species. The tulip poplar, red oak, basswood and under certain conditions the sugar maple would be the trees to save. The elimination of all weed trees then would be the first operation. The removal of the beech is the most pressing need. Likewise the black gum, ironwood and buckeye are a serious hindrance to the regeneration of the poplar and oak. The obstacle in the way of the removal of beech would be the lack of a market for the wood product. A simple method of disposing of the trees would be to girdle and leave them standing, although their removal would be better. These operations will largely aid the regeneration of the poplar, whose most pernicious enemy is the overtopping and dense shade of these weed trees. In many instances it is advisable to resort to planting, especially where sufficient seedlings and seed trees of desirable species do not exist. The tulip poplar, red oak, and in some locations chestnut, are the practical species to consider. The European larch and bald cypress might also be considered. The species mentioned should be used in mixture with some heavy foliaged, tolerant species, preferably the sugar maple or red mulberry. It is especially urgent that the larch and cypress be used with some heavy foliaged species as their leaf crowns are not capable of shading the ground sufficiently to exclude the grass and create the necessary humus and ground cover.

The proper distance of planting will depend somewhat on the species used and other conditions. On an average, 6x6 feet is a safe distance. The heavy and light foliaged trees can be alternated in rows.

THE UPLAND TYPE

This comprises the largest area of the forest lands and is characteristic of the plateau lands. Originally white oak was the predominating species. It has been somewhat superseded by the black and scarlet oak, and pignut and mockernut hickories. The primeval forest consisted of giant white oaks. Few of these specimens remain, and the second growth of white oak is gradually being eliminated in the struggle for existence. There are occasional second growth stands which are thrifty, but the composition is nearly pure. Where the black and white oak occur together the white will eventually be superseded by the black. This type chooses the dryer sites, hence the growth of the trees is usually slow, and the

results of pasturing and over exposure of the soil are very evident. This type is reproducing quite well, the second growth being mostly oaks except where severely pastured. In that case the percent of hickories is on the increase. There are occasionally scattering white ash trees in this type, but where the heavier clays abound and forest conditions are good, reproduction is quite frequently abundant. The stands examined, however, seem to lack the soil fertility and moisture necessary to mature them. Doubtless a heavier foliaged species in mixture would have served to build up their site and hence increase their thriftiness. Moreover, a considerable portion of this second growth is pastured, which is doubly injurious in a dry site of this nature which demands the very best forest conditions.

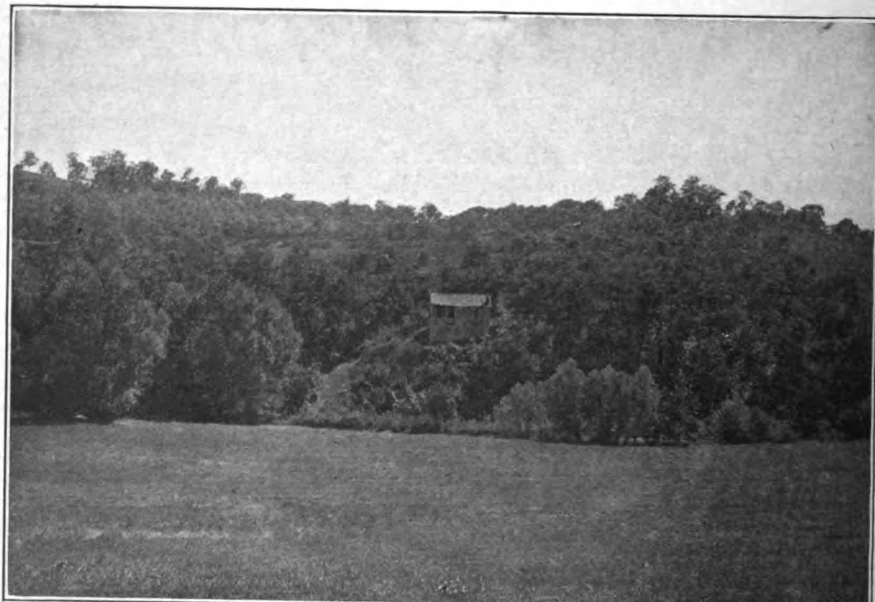


Photo by Secrest

Black locust taking possession of an abandoned field

The east and north slopes are naturally in better silvicultural condition than the north and west slopes. The forest an dsilvicultural conditions are usually poor on the latter, especially where a culled condition of growth exists.

Probably 75 percent of the area of this type has been severely culled over. In the process an excess of black oak has been left.

Quite frequently there occur on the dry, sandy hill tops dense stands of chestnut oak, consisting almost entirely of second growth, which resulted in many cases from stump sprouts. This growth is characterized by an undergrowth of huckleberry and often laurel, the latter occuring only on the thinnest and most barren soils. Occasionally black locust may be found in mixture, usually in an unthrifty condition, however. There are but few original trees of the chestnut oak remaining. Practically all have been removed in the past for tan bark.

PLANS FOR IMPROVEMENT

Grazing is the potent factor influencing this type of woodlot The first step should be to reserve the area from livestock. Owing to the comparatively dry situations upon which this type exists the best possible conditions must be preserved through the accumulation of leaf mold, by means of undergrowth.

The removal of all matured trees, would also be important. In some woodlots large, cull white oaks are standing, and in many instances are doing material harm to young trees. The scarlet oak may be considered a weed tree and its elimination is necessary in the selection of species to form the stand. Wherever the ash tends to reproduce all efforts should be made to favor this species. When ash seed trees are present, all worthless undergrowth should be removed, especially where the crown cover completely covers the ground. This will encourage the reproduction of the ash. An admixture of red maple would improve the quality of the site and be of benefit to the ash.

A considerable number of woodlots of this type consist of fairly normal stands of second growth black oak, varying in size from eight to fifteen inches in diameter. Very little can be done to improve the conditions of these areas except to reserve them from grazing. Occasionally the stands of trees are thin enough on the ground to permit of interplanting. The species which figure in the reconstruction of woodlots of this type are few. The locust would be a good species to interplant where the growth is too thin. On the chestnut oak soil the white pine could probably be used to advantage, as could the shortleaf pine *Pinus echinata*. Red oak could be used on the moister slopes.

PINE TYPE

On western exposures and dry hill tops there may be found occasional groups and mixtures of shortleaf, Jersey, pitch and white pines. The species frequently occur in mixture with black and

chestnut oaks and pignut hickory. These areas are not extensiv nor very valuable. The pines are practically all second growth, an are apparently encroaching upon the hardwoods in the dry sites In many places pine reproduction will be found among the thinne hardwood stands, where it is being fostered by the shade of th latter. The shortleaf, pitch and Jersey pines take possession of ol fields, and in a number of instances they are found slowly encroach ing upon such areas which are in close proximity to seed trees. O the species found, the shortleaf pine is of the most economical im portance as its growth is more rapid, straighter, and the lumbe product is of higher value. While the product of the white pine ha a higher commercial value, it does not exist in sufficient quantitie to be considered except as a valuable tree to be used for futur planting.

Photo by Secr

Pitch pine encroaching on an old field

THE WHITE PINE

This species is found growing upon a limited area on the eas ridge of Leith Run in Grandview Township. It seeks the sout slope and is associated with white, black and chestnut oaks, an beech, white ash, sorrel wood and a small amount of Jersey and pitc pine. The white pine occupies about twenty percent of th mixture. While the trees are existing under poor conditions the

have made fairly good growth, and some of them show two and one-half feet between nodes. On the third fork of Mill creek is another stand which is considerably denser and shows better growth. Some of the stumps indicate a 12 inch tree in 40 years, under natural conditions.

Were the thinning of hardwoods accomplished the area of the pine forests could be considerably extended and the quality of wood product very much improved. In many places the trees stand too thin. They do not prune themselves and the stands are nowhere normal.

OLD FIELD TYPE

This type is commonly met with on the east side of the Muskingum river and it sometimes occurs on the west side. In Independence township about fifteen percent of the forest area comprises the growth which has come up in abandoned fields. Two species figure prominently in this type, the locust and hickory. There are many large thickets of the former, occuring on old fields and pastures where the soil is often too exhausted to produce anything else. Quite frequently it is associated with hickory and sassafras. These stands have come into existence only recently. The presence of large locust trees in close proximity to a sterile field or pasture, upon which no stock was allowed to roam, served to seed these areas, and doubtless much of the reproduction was secured by root suckers. A peculiarity exists here that is rarely met with, viz., the apparent ease with which the locust reproduces itself by seed.

The type is of great importance to the county, and it is being recognized as such.

EXTENSION OF THE OLD FIELD TYPE

The stands of locust as they now exist often lack sufficient density, or are grouped, leaving large spaces unoccupied. The prolific suckering propensities of the locust are commonly known, and it is through this feature that the group may be extended and greater density secured in thin stands.

In breaking the roots of the species a sprout will result. Where extension is desired the ground about the roots of the trees should be broken by plowing furrows about six feet apart in the direction the grove is to be extended. This operation may be kept up each year until a sufficient number of sprouts are secured to restock the area.

In many cases it will be found necessary to remove "weed tree from among the locust. Sassafras and hickories often times cc sume space and overtop the locust.

Negetive by Sponsle

A splendid blue grass pasture produced from once sterile ground by the influence of the black locust. The locust grove is about 25 years old and is valued at $120.00 per acre

EROSION

The erosion and abrasion of soil on hundreds of acres of land this county is one of the startling features evidenced by the study conditions. In many places the soil has been tilled until the vegetal fiber is exhausted and nothing remains but the exposed and gulli surfaces of clay. Thousands of tons of earth are annually carri into the streams and rivers, taking the best soil down to the impe etrable subsoils, and the trouble is just beginning. This erosion not only detrimental to agricultural interests, but is of far great consequence to the water flow, the water stages being influenc unfavorably by the accumulation of soil and silt, resulting in hin rance to navigation in the larger rivers, and the condition at t head waters of each effluent must ultimately be reflected in the flo

of the main rivers. The loss to land owners entailed through erosion is annually enormous. This erosion is not only resulting in the actual deterioration of the soil but also in the loss of paying crops. In some few instances these areas may be profitably reclaimed by the addition of fertilizers and the seeding to grass, but in the vast majority of instances where the wasting process has gullied the land, such a procedure would hardly be practical. Tree planting is the only hope, and the sooner it is recognized the better.

(A detailed report on Landslides and Erosion will be issued by this Station during the current year).

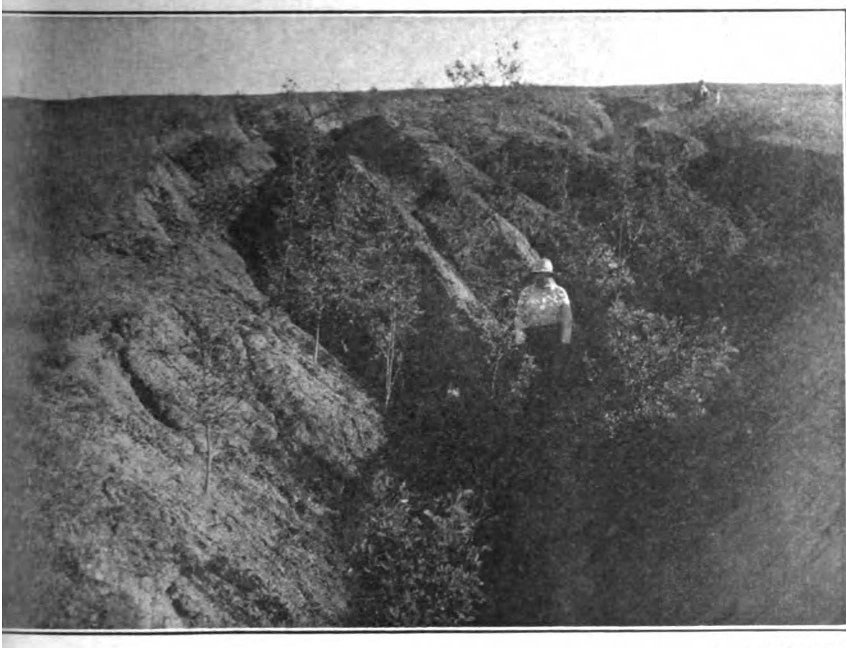


Photo by Secrest

Stopping the wash by planting locusts

THE TULIP POPLAR

One of the most striking arboreal features of the county is the second growth tulip, or yellow poplar grove on the farm of Mr. F. F. Graham, near Vincent, in Barlow township. This grove is situated on a ridge of pure sand which is underlaid with yellow clay. In a sand pit the roots may be seen to extend ten or fifteen feet into the sand. The woodlot is in several stages of growth, the final result of which will be a pure stand of poplar. Among the poplar are growing white ash, red maple, sassafras and dogwood, all of which the poplar will supersede in time.

The tulip poplar is in various stages of development. A por of the growth is about eleven years old, a part sixteen years old another part twenty years old. The latter portion of the grove need of thinning.

Owing to the light leaf canopy of the tulip poplar it would no wise to make a heavy thinning unless a heavy underwood rema to protect the site, and such growth is ceasing to exist in the gr It would doubtless be the best plan to make a heavy thinning underplant with sugar or red maple. In some places the red berry might be used. This would give the poplar an excel chance to develop and at the same time the soil conditions wi preserved and improved by the heavy foliaged maple.

Photo by S

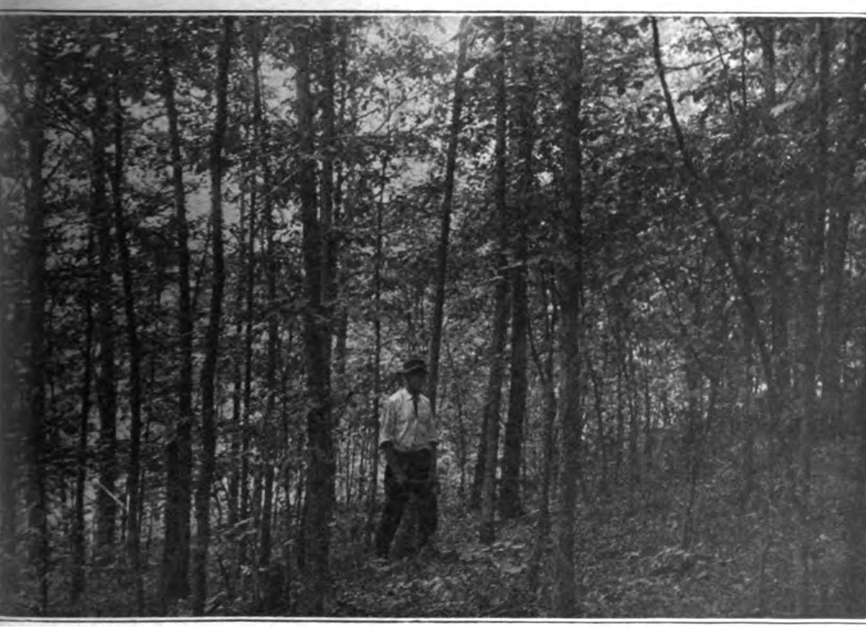
Waste in cutting white oak ties

COMPOSITION OF 20-YEAR-OLD TULIP POPLAR FOREST
DATA FROM AREA 50 FEET SQUARE

Species	Diameter in inches, 4½ feet from ground								Total nu
	1	2	3	4	5	6	7	8	
Tulip poplar............	1	1	3	6	7	5	1	2	35
White ash	1	2		4	5				12
Pignut hickory	2	1							3
Sassafras		1	3	3					7
Red maple..............	1								1
White oak	2								2
Black cherry				1					1
Black gum		2							2

MARKET CONDITIONS

The lack of dependable markets for wood products is the discouraging feature in the practice of forestry. The demand for board stuff and construction material is greater than it was, but that material is almost exhausted. The product now available in the form of the second growth and the culled trees of the original forest which it is often necessary to remove from the woodlot and dispose of, has little or no market value. Coal has practically driven fire wood out of the market, so that usually no value can be placed upon wood for that utilization. In some cases a nominal price may be obtained for mine props. This does not exceed one cent per linear foot. The tie market in many cases is the most profitable when timber of that dimension is at hand. At the present time white and chestnut oak ties are selling at from 50 to 60 cents per tie. Red, black and scarlet oak and chestnut sell from 35 to 50 cents per tie, delivered at the railroad.



Negative by Sponsler
Second growth chestnut oak, Washington county

WASTE LANDS

Washington county contains a total of 297,773 acres of land, 29,328 acres of which is classified as waste land, which is practically ten percent of the area. A portion of this waste is a result of topo-

graphical conditions, and a portion that of erosive processes. The latter form the largest areas, and they are on the increase. Much of the land comprising the steep slopes contains a sparse growth of timber which has neither real nor potential value, much of which has been brought into productiveness by forestry practices. Of more importance are those areas which erode, and they are so numerous and the work of destruction has progressed so far, that cure as well as prevention must be considered.

The best "cure" in most of these cases is trees, but it must first receive recognition as such. Nature herself proceeds in this manner, and the results manifest themselves in the many locust and pine thickets on eroded lands throughout the Appalachian plateau.

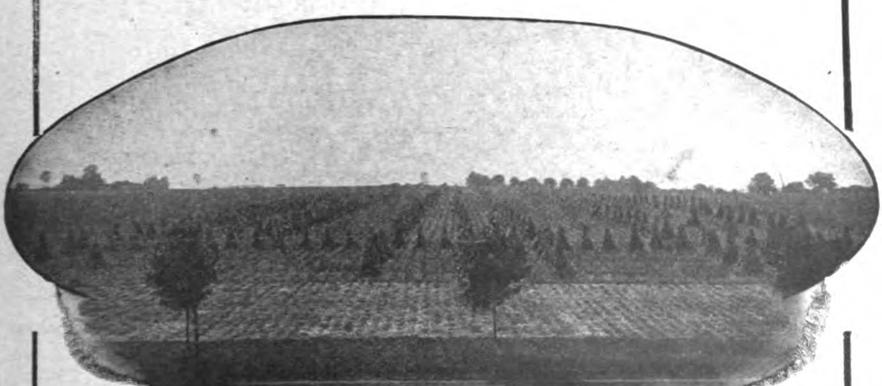
Time, patience, courage and resource will be required to bring these areas back to productiveness and its importance as an agricultural problem in southern Ohio is second to none.

CORN JUDGING: STUDIES OF PROMINENT EAR CHARACTERS IN THEIR RELATION TO YIELD

OHIO
Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., DECEMBER, 1909

BULLETIN 212



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BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 212 DECEMBER, 1909

CORN JUDGING: STUDIES OF PROMINENT EAR CHARACTERS IN THEIR RELATION TO YIELD

BY C. G. WILLIAMS AND F. A. WELTON

The time has perhaps come when this Station is able to draw some conclusions from experimental data as to what ear characters are associated with high yielding corn. Work was begun in a small way five years ago in the study of the relation of length of ear to yield. Four years ago it was extended to a study of the relation of shape of ear to yield, and later to the filling of the tip, the indentation of the kernel, the weight of ear and the effect of previous environment upon the value of seed corn.

It has been thought best to make a preliminary report of this work although the questions asked are a long way from being permanently answered. However, the answers recorded may turn some light upon corn judging, or the selection of seed corn.

In the study of these various characters the aim has been to have the groups compared differ widely with reference to one character only. Little or no attention has been paid to other characters except to have all sorts represented, the thought being that one character would offset its opposite, giving a fairly accurate comparison of the groups and the character studied.

Each group has consisted of from 25 to 100 ears and has been represented by a composite sample of seed made up of a few rows of kernels taken from each ear. While it is well known that ears of orn vary in their ability to yield from perhaps invisible, though heritable characters, in the numbers in which they were used in these tests it is presumed that such variation would be cared for; that is, that high and low yielding ears would be found in each group.

The size of the plots used in this work has been one-tenth acre. The conditions of growth as affected by previous treatment of soil have been quite uniform. For the last sixteen years not a furrow has been plowed, nor a pound of fertilizer put upon one plot without similar treatment being given the other plots of the series the same day.

In planting these test plots an excessive amount of seed has been used and the plots thinned to a uniform stand when the plants were six to eight inches high.

1. THE RELATION OF LENGTH OF EAR TO YIELD

Attention is called in the first place to the relation of length of ear to yield. In Table I is reported a test conducted in 1909 with four varieties of corn. Upon two of these plots corn of the third generation of continuous selection of long and short ears was used. Upon four plots, corn of the second generation, and upon four more, corn of the first generation.

TABLE I: The relation of length of ear to yield, 1909.

Variety	Average length	Average weight	Av. circ 2 in. from butt	Av. circ 2 in. from tip	Yield per acre	Excess length of long ears over short
	Ins.	Ozs.	Ins.	Ins.	* Bus.	Ins.
Clarage (*a*)	8.9	10.6	6.5	5.8	84.77	
Clarage (*a*)	6.6	8.8	6.7	6.1	79.15	
Gain for long ears					5.62	2.3
Leaming (*b*)	9.3	12.1	7.2	5.9	95.18	
Leaming (*b*)	7.1	9.9	7.4	6.4	90.41	
Gain for long ears					4.77	2.2
Darke Co. Mammoth (*b*)	9.7	13.3	7.0	6.2	99.47	
Darke Co. Mammoth (*b*)	7.2	10.9	7.5	6.9	92.70	
Gain for long ears					6.77	2.5
Reid Yellow Dent (*c*)	10.6	13.8	7.0		88.47	
Reid Yellow Dent (*c*)	8.2	11.7	7.2		82.28	
Gain for long ears					6.19	2.4
Leaming (*c*)	9.4	12.8	7.3		92.74	
Leaming (*c*)	7.8	10.4	7.4		90.21	
Gain for long ears					2.53	1.6
Average gain for long ears—10 plots in test					5.18	2.2

(*a*) Third generation of long and short ears.
(*b*) Second generation of long and short ears.
(*c*) First generation of long and short ears.
* Fall weights corrected to a uniform moisture content of 15 percent.

It will be observed that in every instance the long ears lead in yield, by amounts ranging from 2.53 to 6.77 bushels per acre, with an average of 5.18 bushels. It will be noted further that the greatest increase in yield comes in the group in which there is the greatest difference in length between the long and short ears, while the least increase in yield comes in the group in which there is the least difference in length.

However, differences in length of ear are not the only differences existing in these several groups. In Table II we have these same groups arranged so as to compare their differences with reference to other characters, as follows:

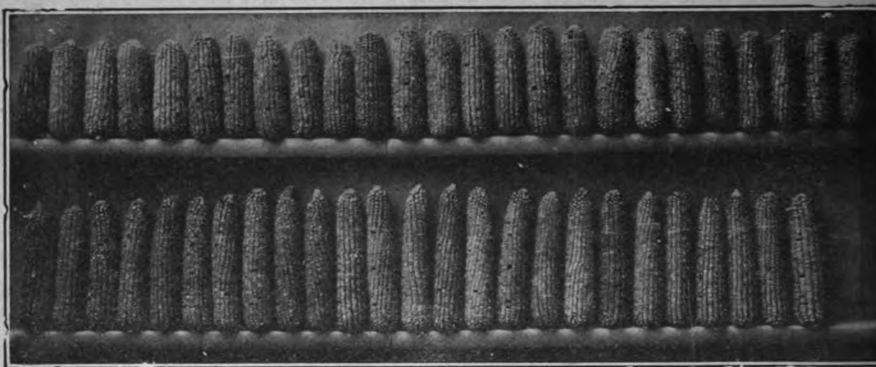
TABLE II: A study of the long and short ears reported upon in Table I with reference to length, weight, shape, circumference and proportion of circumference to length.

Variety	Long or short ears	Excess in length Inches	Excess in weight Ounces	Excess in circumference (butt) Inches	Excess of butt circumference over tip circum. Inches	Excess in yield Bushels	Proportion of circum. to length Percent
1 Clarage	Long	2.3	1.8		0.7	5.62	73.0
2 Clarage	Short			0.2	0.6 *d*		101.5
3 Leaming (*b*)	Long	2.2	2.2		1.3	4.77	77.4
4 Leaming (*b*)	Short			0.2	1.0 *d*		104.2
5 Darke Co. Mammoth	Long	2.5	2.4		0.8	6.77	72.2
6 Darke Co. Mammoth	Short			0.5	0.6 *d*		104.2
7 Reid Yellow Dent	Long	2.4	2.1			6.19	66.0
8 Reid Yellow Dent	Short			0.2			87.8
9 Leaming (*c*)	Long	1.6	2.4			2.53	77.7
10 Leaming (*c*)	Short			0.1			94.9

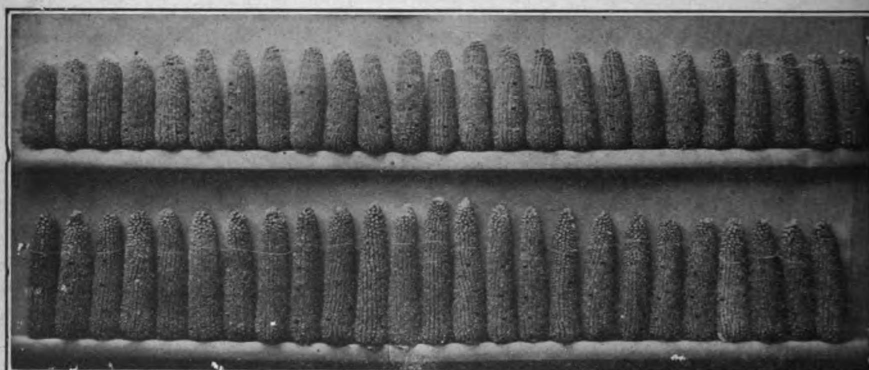
(*b*) Second generation. (*c*) First generation. (*d*) More cylindrical.

It is to be noted, as would be expected, that these groups of long ears average higher in weight of ear also. Is it possible that this excess in weight may have had as much to do with the increase in yield as has the length? That it has something to do with it is probable. Note, however, that, while the group of long ears (5) showing greatest increase in yield and greatest length also stands at the top in weight, there is another group (9) equaling it in weight, but at the other extreme in yield. The latter group is lacking in *length* as well as in yield.

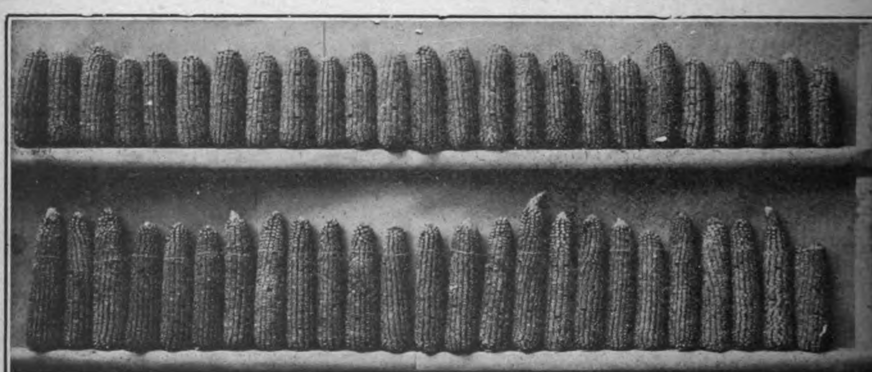
The short ears—and low yielders—invariably exceed the long ears in circumference. This would seem to indicate the impossibility of increasing the yield of short ears by increasing their circumference to make good their lack in weight, providing weight be a factor of significance in increasing yield.



Darke Co. Mammoth. Long and short ears



Leaming. Long and short ears.



Clarage. Long and short ears.

TABLE III: The relation of length of ear to yield. Summary of 22 tests on 44 tenth-acre plots, 1905-1909.

Year	Variety	Long or short ears	Yield of shelled corn per acre * Bus.	Increase in yield Bus.
1909	Clarage	Long	84.77	5.62
	Clarage	Short	79.15	
	Leaming	Long	93.96	3.65
	Leaming	Short	90.31	
	Darke Co. Mammoth	Long	99.47	6.77
	Darke Co. Mammoth	Short	92.70	
	Reid Yellow Dent	Long	88.47	6.19
	Reid Yellow Dent	Short	82.28	
	Average gain for long ears			5.18
1908	Clarage	Long	68 22	0.45
	Clarage	Short	67 77	
	Leaming	Long	73 50	4.40
	Leaming	Short	69 10	
	Darke Co. Mammoth	Long	78.25	5 06
	Darke Co. Mammoth	Short	73.19	
	Average gain for long ears			3.31
1907	Clarage	Long	64.95	
	Clarage	Short	65.38	0.43
	Leaming	Long	63.41	3.15
	Leaming	Short	60.26	
	Reid Yellow Dent	Long	58.62	
	Reid Yellow Dent	Short	60.20	1.58
	Average gain for long ears			0.38
1906	Clarage	Long	66.88	8.12
	Clarage	Short	58.76	
	Leaming	Long	78.40	6.02
	Leaming	Short	72.38	
	Average gain for long ears			7.07
1905	Leaming	Long	97.05	4.20
	Leaming	Short	92.85	
Combined average of 22 tests, gain for long ears				3.97

* For 1909 ear corn corrected to 15 percent moisture content, 70 pounds of which will approximate shelled corn bushels.

In Table III is given a summary of the 22 tests conducted during the past five years in the study of long as compared with short ears. Many of these tests were in duplicate. Of those duplicated, the average of the two plots is given.

It will be noted that the long ears are in the lead each of the five years, although one year the lead is insignificant. The combined average of all the tests gives an advantage of 3.97 bushels in favor of the long ears.

Illustrations on page 216 give an idea of the character of the ears compared.

What has been the tendency of this continued selection of long and short ears upon the length of ear of the crop grown?

This continuous selection began with the Clarage corn in 1907. Thirty-nine short ears were selected, averaging 7.1 inches in length, and 39 long ears averaging 9.4 inches. A composite sample, made up of a few rows of kernels from each ear, was planted upon tenth-acre plots, the plot from the short ears being grown beside the plot from the long ears each year, no effort being made to prevent inter-crossing.

The length of each ear of corn grown from these selections was measured. The average length of ear from the short ears was 7.12 inches; from the long ears 7.56 inches: a difference of .44 inch. The length was measured about a month after husking and before the ears were fully shrunken, while the seed ears planted each year have been measured in the spring, shortly before planting.

For the plantings of 1908 and 1909 short and long ears were selected from the preceding crop of the same class. The crop was not measured in 1908, but was in 1909, as in 1907, when the average length of ear was 6.87 inches for the short ears and 7.92 inches for the long ears. A difference of 1.05 inches in 1909 as compared with 0.44 in 1907.

It should perhaps be stated that ears of all lengths, including nubbins, were measured both years.

TABLE IV. Variation in length of ear in seed and progeny.

Year	Seed used			Crop harvested			* Yield per acre		
	Long ears, Av. length Inches	Short ears, Av. length Inches	Difference Inches	Long ears, Av. length Inches	Short ears, Av. length Inches	Difference Inches	Long ears Bus.	Short ears Bus.	Difference Bus.
1907........	9.43	7.11	2.32	7.56	7.12	0.44	64.95	65.38	—0.43
1909........	8.90	6.60	2.30	7.92	6.87	1.05	84.77	79.15	+5.62
Comparing 1909 with 1907	—0.53	—0.51	—0.02	+0.36	—0.25	+0.61	+19.82	+13.77	+6.05

* Shelled corn for 1907. Ears, corrected to 15 percent moisture in 1909.

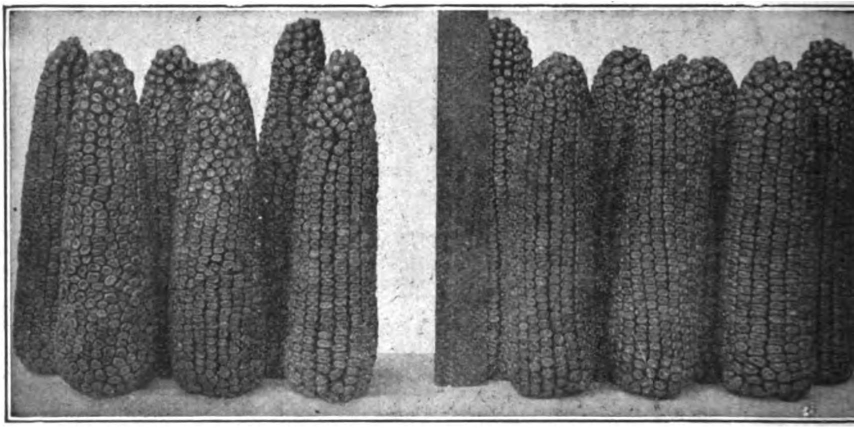
While the seed of the long ears used in 1909 is not of as great average length as that of 1907, this fact would seem to be due to a matter of environment. At any rate the inherent character seems to be present, for it is asserted in the progeny.

That the average length of ear can be quite rapidly changed is probable. The plant breeder will be interested in accounting for this change. Are we adding together the slight fluctuations discoverable year by year, or did we have in the first selection all we now have in these heritable characters, the advance made being due, not to the addition, little by little, of the character in question, but to the purification of the type by the weeding out of the opposite character—to subtraction rather than addition? The practical corn grower will be interested in the fact, though possibly not in the theory.

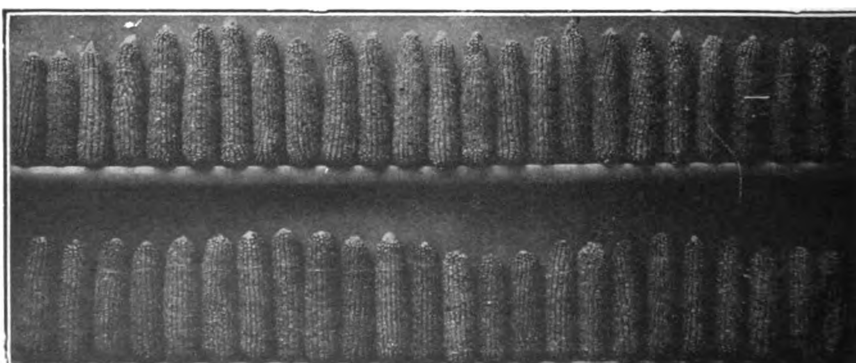
Conclusion: If a given quantity of seed corn be divided into two groups, one composed of ears below the average length and the other above, the longer ears will out-yield the shorter. We have no evidence that selection for extremely long ears increases the yield above those of medium length. The difference in yield thus far has seemed to be due to a lessened yield resulting from the selection for short ears, rather than an increased yield from the selection for long ears.

2. THE RELATION OF SHAPE OF EAR TO YIELD

If there has been one ear character insisted upon more strongly than another in the corn judging of the country it has been that of cylindricity. In 1906 this Station began some studies of the relation of shape of ear, as regards cylindricity, to yield. In the selection of varieties to be used in these tests the aim was to include varieties having quite different tendencies; varieties in which the cylindrical ear predominated, and varieties in which the decidedly tapering ear was the rule. Accordingly, what I may call the Ohio, or old type of Leaming corn has been used throughout the test as representing the tapering varieties, and the Darke County Mammoth, another fairly distinct Ohio strain, as representing the varieties tending toward the cylindrical ear. During two of the four years of this test Reid Yellow Dent has also been included. Cylindrical and tapering ears from each variety have been compared side by side, selected to vary as widely in each direction as could well be found in corn that would pass at all for seed corn. A consultation of tables and illustrations will give an idea of the type of corn tested.



Leaming. Cylindrical and tapering ears.



Darke Co. Mammoth. Cylindrical and tapering ears.

TABLE V: The relation of shape of ear to yield, 1909.

Variety	Cylindrical or tapering	Average Length Ins.	Average Weight Ozs.	Av. circum. 2 inches from Butt Ins.	Av. circum. 2 inches from Tip Ins.	Yield per acre *Bus.
Leaming (*b*)	Cylindrical	8.1	11 4	7.2	6.3	93.71
Leaming (*b*)	Tapering	8.4	10 3	7 0	5 6	93.45
Gain for cylindrical ears						0.26
Darke Co. Mammoth (*b*)	Cylindrical	8 2	12.8	7.3	6.8	94.43
Darke Co. Mammoth (*b*)	Tapering	8.8	11.5	7.0	6 0	93.64
Gain for cylindrical ears						0.79
Reid Yellow Dent (*c*)	Cylindrical	9.3	13.8	7.2	6.5	90.08
Reid Yellow Dent (*c*)	Tapering	10.0	12.7	7.2	5.5	85.97
Gain for cylindrical ears						4.11
Leaming (*c*)	Cylindrical	8.2	12.0	7.7	6.5	88.46
Leaming (*c*)	Tapering	8 8	11.8	7.4	5.6	89.31
Gain for tapering ears						0.85
Average gain for cylindrical ears						1.08

(*b*) Second generation of cylindrical and tapering ears.
(*c*) First generation of cylindrical and tapering ears.
* Corrected to a uniform moisture content of 15 percent.

In Table V is given the result of the comparison of cylindrical with tapering ears in the tests of 1909. It will be discovered that the greatest variation in the character studied is found in the case of Reid Yellow Dent selections, and only in this variety is there a variation in yield of moment. This variation is in favor of the cylindrical ears.

TABLE VI: A study of the cylindrical and tapering ears reported upon in Table V, with reference to length, weight, shape, circumference and proportion.

Variety	Cylindrical or tapering	Excess in length Inches	Excess in weight Ounces	Excess in circum. (butt) Inches	Excess of butt circ. over tip circ. Inches	Excess in yield Bushels	Proportion of circ. to length Percent
Leaming (*b*)	Cylindrical		1.1	0.2	0.9	0.26	88.9
Leaming (*b*)	Tapering	0.3			1.4		83.3
Darke Co. Mammoth	Cylindrical		1.3	0.3	0.5	0.79	89.0
Darke Co. Mammoth	Tapering	0.6			1.0		79.6
Reid Yellow Dent	Cylindrical		1.1	0	0.7	4.11	77.4
Reid Yellow Dent	Tapering	0.7		0	1.7		72.0
Leaming (*c*)	Cylindrical		0.2	0.3	1.2		93.9
Leaming (*c*)	Tapering	0.6			1.8	0.85	84.1

(*b*) Second generation. (*c*) First generation.

The variation in the different ear characters of the variety types is brought out in Table VI, but this table offers little explanation of the results secured. While the cylindrical exceed the tapering ears in weight, the greatest excess in weight is not associated with the greatest excess in yield per acre.

TABLE VII. The relation of shape of ear to yield. Summary of 18 tests on 36 tenth-acre plots, 1906-1909.

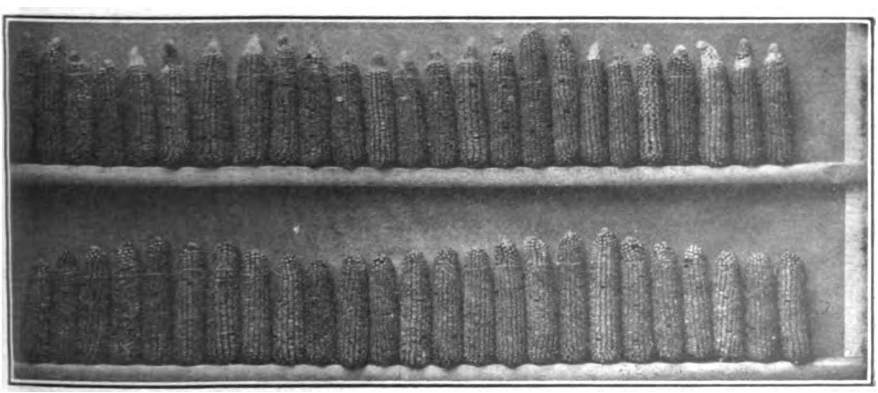
Year	Variety	Cylindrical or tapering	Yield of shelled corn per acre * Bus.	Increase in yield Bus.
1909	Leaming	Cylindrical	91.08	
	Leaming	Tapering	91.38	0.30
	Darke Co. Mammoth	Cylindrical	93.43	0.79
	Darke Co. Mammoth	Tapering	93.64	
	Reid Yellow Dent	Cylindrical	90.08	4.11
	Reid Yellow Dent	Tapering	85.97	
	Gain for cylindrical ears			1.08
1908	Leaming	Cylindrical	76.16	1.47
	Leaming	Tapering	74.69	
	Darke Co. Mammoth	Cylindrical	69.61	
	Darke Co. Mammoth	Tapering	71.51	[illegible]
	Gain for tapering ears			[illegible]
1907	Leaming	Cylindrical	59.81	
	Leaming	Tapering	60.92	[illegible]
	Darke Co. Mammoth	Cylindrical	63.74	[illegible]
	Darke Co. Mammoth	Tapering	61.10	
	Reid Yellow Dent	Cylindrical	60.49	
	Reid Yellow Dent	Tapering	60.91	[illegible]
	Gain for cylindrical ears			0.37
1906	Leaming	Cylindrical	70.13	
	Leaming	Tapering	76.23	6.10
	Darke Co. Mammoth	Cylindrical	73.34	
	Darke Co. Mammoth	Tapering	76.72	3.38
	Gain for tapering ears			4.74
'06-'09	Combined average of 18 tests, gain for tapering ears			0.87

* For 1909, ear corn corrected to 15 percent moisture.

In Table VII is given the summary of 18 tests, extending over four years. In two of these years the cylindrical ears lead slightly, while in two the tapering ears lead. The combined average shows a gain of 0.87 bushel in favor of the tapering ears. It is evident at a glance that there is not the consistent variation in yield in favor of either character that is found in the case of the long and short ears. In considering these data it seems that we are dealing with a character of minor importance, and hence the conclusion is forced upon one that until more decisive evidence is forthcoming, it is unwise to discriminate to any great extent in favor of either the tapering or cylindrical ear.

3. BARE VS. FILLED TIPS

In 1907 a test was started in which ears of Clarage corn having ¾ to 1½ inches of bare cob at the tip of the ear were compared with ears completely filled out. In the ear-row tests of several years preceding it had been found that the high yielding ears were fully as apt to be bare at the tip as to be filled out, and accordingly the above test was started to study the relation of this character to yield in a larger way. The first year the average yield of the two plots planted with bare-tipped seed was 58.21 bushels, and of the plots planted with the filled-tipped seed, 57.79 bushels; a slight gain of 0.42 bushels for the bare tips.



Clarage. Filled and bare-tipped ears.

From each of these types 25 similar ears were selected for planting in 1908—bare tips from bare tips and filled tips from filled tips. The results the second year were in favor of the filled tips, with a gain of 1.45 bushel, the yields being 64.07 bushels for the bare tips and 65.52 bushels for the filled tips.

The selection was continued in like manner for the test of 1909, resulting in a gain of 2.19 bushels in favor of filled tips, the yields being 84.37 and 86.56 bushels per acre.

Tabulating the results for the three seasons' work, they stand as follows:

TABLE VIII: Three crops from bare and filled tips.

Year	Bare or filled tips	Yield of shelled corn per acre Bus.	Gain per acre Bus.
1907	Bare	58.21	
	Filled	57.79	
	Gain for bare tips		0.42
1908	Bare	64.07	
	Filled	65.52	
	Gain for filled tips		1.45
1909	Bare	84.37	
	Filled	86.56	
	Gain for filled tips		2.19
Average gain for filled tips			1.07

In the light of the above facts the tendencies of deliberate selection for bare tips would seem to be in the direction of a decreased yield. The yield of the original selections was slightly in favor of the bare tips, indicating that the foundation ears of the bare-tipped group were the equal, at least, of the filled-tipped. Their gradual falling off in yield as compared with the latter, seem to show the above mentioned tendency.

It is of interest to note the habit of these groups to reproduce their characteristic tip. The following table gives information regarding the seed ears used in 1909 and the crop procured therefrom.

TABLE IX: Bare tips vs. filled tips. Crop of 1909.

THE SEED USED.	BARE TIPS	FILLED TIPS
Average length of ear	8.4 ins.	8.0 ins.
Average weight of ear	9.4 ozs.	10.6 ozs.
Average circumference	6.6 ins.	6.7 ins.
Average percent of grain	83.6 %	84.5 %
THE CROP HARVESTED		
Yield per acre	84.37 bus.	86.56 bus.
Average length of ear	7.70 ins.	7.52 ins.
Average length of bare tips	1.03 ins.	0.53 ins.
Ears having filled tips	3.7 %	20.1 %

It will be observed that only 3.7 percent of the ears grown from the seed ears having bare tips had completely filled tips, while 20 percent of the ears grown from filled-tipped seed had completely filled tips. As might be expected the greater part of the ears and nubbins in both lots were bare at the tip. The sum total of inches of bare tips divided by the total number of ears harvested gives an average of 1.03 inch of bare tip *per ear* for the bare-tipped lot and 0.53 inch for the filled-tipped lot.

The average length of ear was greater by 0.18 inch in the case of the crop from the bare, as compared with the filled tips. If, however, we count only that portion of the ear length which is filled with grain, the filled tips lead by 0.32 inch.

Other things being equal, the continued selection of ears having ¾ to 1½ inch of bare cob at the tip will tend to reproduce ears having this character, reducing the percentage of ears having filled tips, and to reduce the yield.

4. ROUGH VS. SMOOTH-DENTED EARS

The relation of the indentation of kernel to yield has been studied both in ear-row work, and also in plot work, in which rough and smooth types of the same variety were compared side by side. The results of the ear-row tests have been in favor of the smooth type, showing a gain of 2.84 bushels per acre over the rough type. The ear-row tests extend over a period of five years.

The plot work with these types was started in 1908. The results for the two years are as follows: For 1908, a gain of 0.99 of a bushel in favor of the rough-dented ears. For 1909, a gain of 2.17 bushels in favor of the smooth-dented ears. This reversal of results may be significant, or it may not. Two or three more years of this continuous selection will give some important information. The fact that the rough ears were superior the first season tested would indicate that they were inherently the equal of the smooth selections.

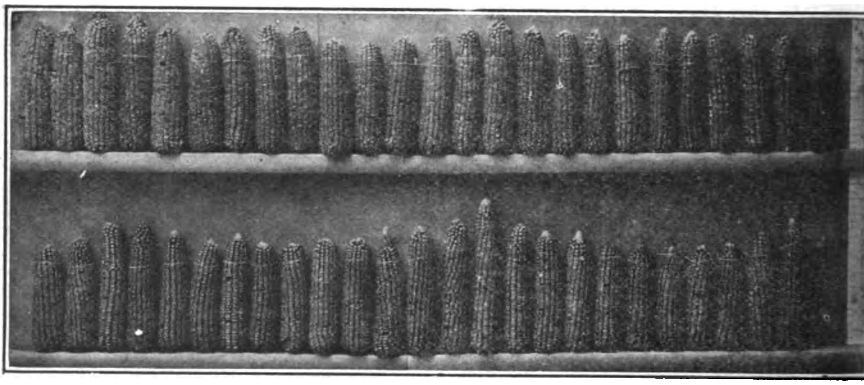
The character of the seed ears used in 1909 is recorded in the following table:

TABLE X: Rough vs. smooth-dented ears. Crop of 1909.

	ROUGH	SMOOTH
Average weight of ears	10.8 ozs.	9.6 ozs.
Average length of ears	8.3 ins.	8.1 ins.
Average circumference of ears	6.8 ins.	6.3 ins.
Average percent of grain	84.2	80.7
Proportion of circumference to length	81.9 %	77.7 %
Yield per acre	88.69 bus	90.86 bus.

It will be noted that the rough-dented ears exceed the smooth in weight, length, circumference and percent of grain. Several of these characters, when studied under conditions in which they were dominant, have favored an increase in yield; but in a modified form, and associated with the more pronounced character of roughness in indentation, they have given way to the smooth type.

Taking into consideration both the ear-row and the plot tests, it seems that the evidence at present is in favor of the smoother-dented ears as being the more productive.



Clarage. Smooth and rough-dented ears.

5. HEAVY VS. LIGHT SEED EARS

As reported in Circular 71, this Station had found the heavier ears in its ear-row tests outyielding the lighter. This was for the years 1904-1906. Bringing this report down to 1909 these tests continue to tell the same story, the heavier ears giving a slight advance in yield.

It should be stated that extremes were not sought for in the selection of seed ears for this ear-row work, but in the selection of otherwise desirable ears there was some variation in weight. Of about 400 ears tested, if the heaviest 40 percent be thrown into one group and the lighest 40 percent into another, we find the average difference in weight of these two groups to be 2.46 ounces per ear, and the difference in yield to be 2.08 bushels per acre.

With the numbers involved and the varying conditions of growth during the different seasons it would seem that this variation in yield might safely be attributed to the variation in weight of seed ears.

In 1908 the Station started a tenth-acre plot test in which 50 representative heavy ears were compared with an equal number of lighter ears. The test was continued in 1909 with heavy ears selected from the crop grown from heavy ears in 1908 and with the light ears selected in a similar manner.

The yields for the two seasons' tests are as follows:

TABLE XI: Yields of heavy and light ears.

Year	Heavy or light ears	Yield of shelled corn per acre Bus.	Gain per acre Bus.
1908	Heavy	65.73	
	Light	65.10	
	Gain for heavy ears		0.63
1909	Heavy	91.13	
	Light	87.90	
	Gain for heavy ears		3.23
Average gain for heavy ears			1.93

This plot test must continue longer before it will be safe to draw conclusions from it alone. Did it not confirm the ear-row tests of the past five years we should not have recorded it at this time. The two tests taken together, however, would seem to indicate a value for the heavy-weight ear. This sort of ear must not be confused with the overgrown and immature ear of large size.

It will be noted that the heavy ears take a more decided lead in 1909. It is proper that the measurements of these two groups of ears as used in 1909 be recorded, that they may be compared with other ears used in the other tests. Also see illustration.

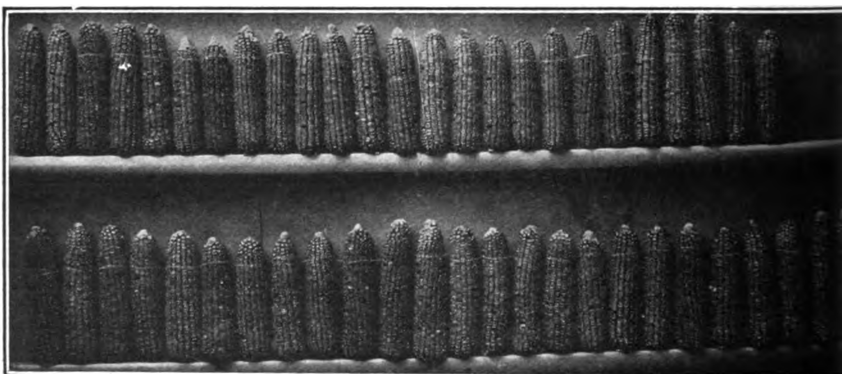
TABLE XII: Heavy vs. light ears. Crop of 1909.

Seed used	Heavy	Light
Average weight of ears	11.6 ozs.	9.4 ozs.
Average length of ears	8.6 ins.	8.3 ins.
Average circumference of ears	6.9 ins.	6.2 ins.
Proportion of circumference to length	80.2 %	74.7 %
Average percent of grain	84.2 %	80.1 %
Crop harvested		
Yield per acre	91.13 bus.	87.90 bus.
Average weight of ears	11.75 ozs.	11.03 ozs.

In computing the average weight of ears in the crop harvested, upwards of 1000 ears were included in each group.

In considering the above data it will be noted that weight of ea and percent of grain both vary widely. It may be asked, which, either, is responsible for the variation in yield? Our tests to da show that weight of ear is a better indication of high yielding see ears than percent of grain.

For instance: If the same 400 seed ears above mentioned divided into two groups, one containing the 40 percent having th highest percent of grain, the other the 40 percent having the lowe percent of grain, we find the former seed ears averaging 86 percent of grain and yielding 81.9 bushels per acre, and the latte averaging 81.8 percent of grain and yielding 83.1 bushels.



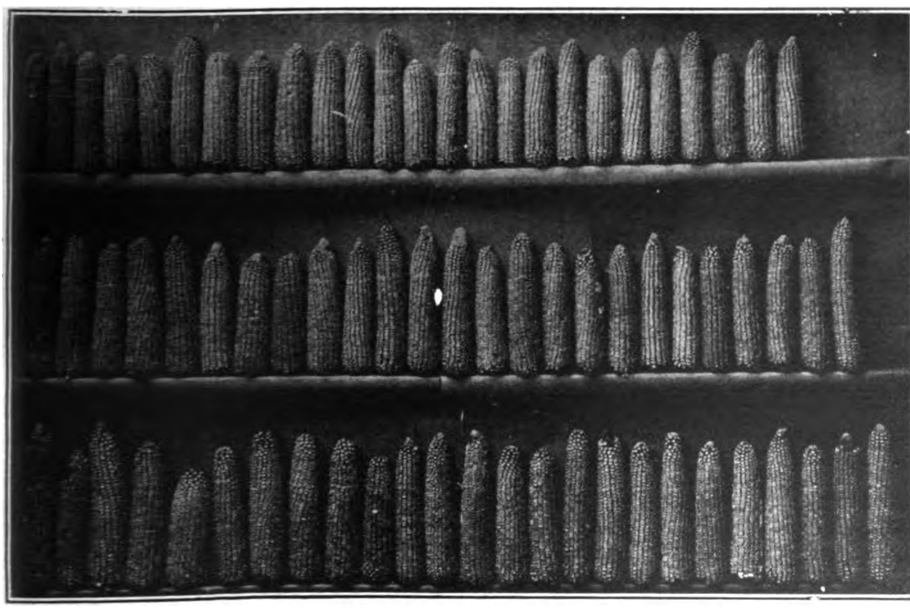
Clarage. Heavy and light ears.

In order to test this ear character under different conditi tenth-acre plot test was started this season, 1909. Two hu fairly good seed ears were chosen. Each ear was shelled separ and its percent of grain determined. The 20 ears having the hig percent of grain were thrown into one group and the 20 having th lowest percent into another. The former averaged 86.09 percen grain and the latter 79.67 percent. The yield per acre as weighe from the field is 104.00 bushels for the high percent strain and 107.5 bushels for the low. At this writing we do not have the shelled cor records. This test will be continued, the selection of high and lo percent grain being continuous.

For the present it may be said that weight of ear is worthy o attention in the selection of seed ears.

6. THE EFFECT OF THE PREVIOUS ENVIRONMENT OF CORN UPON ITS VALUE AS SEED

There have long been prevalent among corn growers quite definite ideas as to the propriety of taking seed corn grown under favorable conditions of soil to less favorable conditions, and vice versa. In order to study the effect of previous conditions of growth upon future crops, this Station began a test in 1907 in which seed corn selected in 1906 from the best manured plot in the fertility work of the Station was compared with corn from an adjoining unfertilized plot. It should, perhaps, be stated that the fertility plots mentioned have been under the same treatment—the one well manured for two crops of the 5-crop rotation, the other continuously unfertilized—for the past sixteen years.



From bottom to top: one, three and five plant strains.

The two lots of seed corn will be hereafter described as "rich" and "poverty" strains of Clarage corn. They were grown on plots side by side, under very favorable soil conditions in our regular variety test plots. In 1908 and 1909 new seed was secured from the original fertility plots and tested as in 1907.

Beginning in 1907 the rich and poverty strains have been grown upon the corresponding plots in the fertility work, the selection being continuous.

The results of the three tests thus far conducted are not convincing. In 1907 the poverty strain led by 0.98 bushel. In 1908 the rich strain by 2.32 bushels. In 1909 the poverty strain led again by 3.80 bushels. The average gain for the poverty strain is accordingly 0.82 bushel per acre.

Attempting to get an answer to the same question from another angle, this Station has been comparing seed ears selected under conditions of normal stand with ears selected without knowledge of stand, i. e., from the wagon. In each instance the best seed ears readily obtainable were selected. Averaging the tests of 1906-1908, the seed ears selected under normal stand have given an increase in yield of 2.36 bushels per acre.

In 1909 this test was changed to make possible more accurate knowledge as to the conditions of stand. Seed ears for use in this work were selected from the "thick and thin" planted plots of 1908. For this use the twenty-five largest and best ears obtainable were selected from the plots upon which corn was growing at the rates of one plant per hill, three plants per hill and five plants per hill. These three lots of seed known as the one, three and five plant strains were planted on adjoining plots and in duplicate. The conditions of growth in 1909 were made as uniform in every way as possible. Interplanted with these three strains were the regular check plots. The yields given in the table below are corrected to a moisture content of 15 percent.

TABLE XIII: One, three and five plant strains of corn. Crop of 1909.

Strain	Average weight of ears Ounces	Average length of ears Inches	Average circum. of ears Inches	Proportion of circum. to length Percent	Average percent of grain	Yield per acre Bus.
One plant	12.0	9.4	6.9	73.4	82.5	91.49
Three plant	10.0	8.8	6.6	75.0	84.0	91.74
Five plant	8.0	7.9	6.3	79.7	82.5	92.58

The differences in yield are of course slight. It is of interest to note, however, that seed ears which are inferior in size and appearance (see illustration as well as table) because of environment are not necessarily inferior in hereditary value. It would seem to be important to know something of the conditions under which an ear of corn is grown before undertaking to tell very much about its value as a seed ear.

In the latter test, as in the rich and poverty strain test, it is evident that under the unfavorable conditions of fertility or stand the ears will be small, and few or none grade as seed ears. May it not be possible, however, that if the cream be skimmed off, one will get a higher quality of seed after all? Whether nature, under "the survival of the fittest," will bring to the front individuals of superior merit, or not, remains for future tests to determine.

7. THE GERMINATION BOX AS AN INDEX TO HIGH YIELDING EARS

It is a fact well known to everyone who has conducted germination tests with corn that the kernels from some ears germinate much quicker than from others; that in a group of 100 ears, not infrequently a half dozen or more will be out of the soil, and an inch or two high before the laggards appear above ground. Is this precocity an indication of superiority as regards yield? Will the "first ups" out yield the "last ups?" If they could be depended upon to do so, as has sometimes been asserted, the germination box could be substituted for the ear-row test, and not only much labor be saved, but more rapid strides taken in the direction of corn improvement.

In order to turn light upon this question a test was conducted in 1907. Six hundred ears were germinated in a shallow box filled with clay loam soil, the kernels being covered with an inch of soil. Data were gathered regarding the order of the appearance of the plants above ground twice in 24 hours. In each lot of 150 ears the 10 ears which came though the soil first were put in one class and the 10 which came up last in another class. Only those ears were considered of which every kernel planted grew. The average variation in the appearance of the plants above ground of the two lots was 48 hours.

A composite sample of seed was made up representing each ear, and two tenth-acre plots were planted from each lot.

The yields of these plots were as follows:

TABLE XIV: First ups and last ups.

Class		Yield of shelled corn per acre
Plot No. 46	First ups	63.71 Bushels
Plot No. 47	Last ups	66.90 "
Gain for Last ups		3.19 "
Plot No. 50	First ups	66.66 "
Plot No. 51	Last ups	69.16 "
Gain for Last ups		2.50 "
Average gain for Last ups		2.84

The same differences in the rapidity of germination were noted in the field as in the germination box. These differences appear to be due to the comparative hardness of the kernels from the different ears and their consequent capacity for rapidly absorbing moisture. The larger the proportion of soft, white starch in the kernel the more rapidly it takes up water and the sooner it germinates. Variation in the thickness and imperviousness of the hull may have something to do with it also.

The germination box is exceedingly useful in weeding out ears injured by the careless handling of seed corn. The more nearly the conditions of growth in the box conform to field conditions, the more valuable will be the test. Further than this the germination test seems to have little value.

As a matter of experiment in its ear-row tests, this Station has found that where enough seed has been planted so that a uniform stand of plants could be had by thinning, a considerable falling off in percent of germination in individual ears has been no sure indication of inferiority in yield. Dividing the ears tested in its ear-row work for the last five years into two classes, in one putting that 40 percent of the ears showing best germination, and in the other the 40 percent showing poorest; the average yield of the two lots has varied but .68 of a bushel. This variation is in favor of the lot showing the best germination.

8. ADAPTABILITY: OF FIRST CONSIDERATION IN THE SELECTION OF SEED CORN

This is true as applied to varieties, and to individual ears within a variety. The loss Ohio corn growers sustain by purchasing unacclimated and ill adapted varieties of corn for seed uses is very great. It is to be feared that the stimulus given the seed trade by the corn shows, with their high prizes, is increasing the trouble from this source. As illustrating the losses incident to the use of varieties not acclimated to the locality where grown, attention is called to the following table which gives the yield per acre, together with some idea of the quality of the product, of seven different varieties as grown at this station in 1908. Similar results are occurring every year in our variety test work and are duplicated upon many corn farms in every county in this state.

TABLE XV: Variation in adaptability of different varieties of corn; 1908.

Variety	Date of tasseling	Average height of plants Ft. Ins.	Percent of moisture as husked	Bushels of shelled corn per acre	Weight per bu. of shelled corn Lbs.	Pounds of stover per acre
Hildreth Yellow Dent, Kansas	Aug. 8	11—6	33.7	57.69	49.00	6,720
Reid Yellow Dent, Illinois	Aug. 1	10—6	25.0	67.19	50.00	4,700
Reid Yellow Dent, Southern Ohio	July 30	10—0	22.4	69.91	50.50	4,240
Darke Co. Mammoth, Southern Ohio	July 28	9—10	21.0	73.12	53.50	4,167
Leaming (early strain) Southern Ohio	July 27	9—9	20.7	74.78	52.50	3,770
Ohio 84-6055, O. A. E. S.	July 24	9—10	18.7	78.76	54.50	3,760
Clarage, O. A. E. S.	July 24	9—6	17.8	68.07	54.50	3,533

The above table calls for little comment. While the figures given seem to discourage the introduction of new varieties, they apply to the wholesale introduction only. It is possible to try out new varieties of promise in a small way, and by the careful selection of ears from plants which come nearest to being adapted to local conditions, to gradually acclimate any variety which seems to have merit.

The variation in individual plants which makes this sort of improvement possible will be appreciated by any one who has conducted an ear-row test and kept records regarding the data recorded in the following table:

TABLE XVI: Variation in individual ears of the same variety as judged by their progeny in ear-row work; 1909.

Ear number	Date of tasseling	Date of silking	Height of plant Ft. Ins.	Height of ears Ft. Ins.	Percent of moisture at husking	Yield per acre corrected to 15 % M. Bus.
9002	July 30	Aug. 4	10—2	4—2	30.8	86.30
9067	July 23	July 28	7—5	2—6	23.0	50.84
9015	July 29	Aug. 4	9—10	3—11	31.6	77.13
9025	July 22	July 27	8—8	3—2	25.2	76.16
9011	July 28	Aug. 4	9—2	4—0	32.9	93.19
9063	July 24	Jnly 29	8—4	3—3	24.8	67.17
9016	July 30	Aug. 4	9—8	4—7	32.1	87.08
9007	July 24	July 29	8—9	3—0	26.9	91.64
9061	July 28	Aug. 1	9—7	3—9	29.2	73.61
9056	July 23	July 29	8—1	3—4	28.5	68.35
9013	July 28	Aug. 2	8—8	3—6	27.0	80.02

The Ohio farmer should grow in a large way only such varieties as have proved their worth for a series of years under such conditions as prevail in his immediate locality. If satisfactory native varieties are not obtainable, approved new varieties may be tested in a small way and gradually adapted to local needs as indicated.

9. A FULL STAND OF PLANTS

The importance of having a full stand of plants is appreciated by more corn growers than have yet been able to attain it. As to what constitutes a full stand, there is a considerable difference of opinion. This difference of opinion is, to some extent, a difference of fact, for under different conditions of soil and climate different stands are needed. And yet it is probable that much of this difference of opinion is mere opinion, without any basis of fact.

TABLE XVII: Thick and thin planting of corn.

No. plants per hill	Average weight of ears	Percent of		Yield of shelled corn per acre	Pounds stover per	
		Nubbins	Barren plants		Acre	Bushel of corn
			1904			
1	.635	11.5	1.8	30.79	1,750	56.8
2	.578	21.3	1.9	48.77	2,500	51.3
3	.557	21.1	3.9	60.46	3,610	59.7
4	.502	27.1	5.1	65.40	3,775	57.7
5	.431	37.1	10.3	59.73	4,090	68.5
			1906			
1	.701	7.7	2.6	33.01	2,680	81.2
2	.676	9.9	2.3	59.68	3,870	64.9
3	.594	15.7	2.9	73.96	4,350	58.8
4	.507	25.2	5.7	78.47	4,580	58.4
5	.429	42.8	9.6	78.14	5,500	70.4
			1907			
1	.763	10.1	1.9	28.76	2,848	99.0
2	.623	19.6	3.2	41.14	3,791	92.2
3	.474	34.3	7.9	40.09	4,147	103.4
4	.405	48.0	15.9	39.09	5,437	113.5
5	.354	58.5	24.5	35.91	5,695	158.6
			1908			
1	.627	11.8	2.6	33.32	2,660	79.8
2	.625	12.5	2.0	51.47	3,400	66.1
3	.549	6.9	1.1	62.62	3,870	61.8
4	.459	13.4	2.9	64.85	4,190	64.6
5	.395	21.0	2.9	67.40	4,590	68.1
			1909			
1	.740	18.1	1.1	*37.67	3,300	88.4
2	.780	8.8	0.8	66.57	4,710	70.8
3	.710	11.6	1.8	85.30	5,670	66.5
4	.622	12.6	5.3	93.78	6,300	67.2
5	.565	20.6	6.9	102.96	6,990	67.9

* Yield for 1909 in ears reduced to a 15 percent moisture content.

As a guide for such conditions as those which obtain at this Station, namely, a silt loam soil of the Waverly series, manured on a clover sod with 8 to 12 tons of phosphated manure from the stable or manure shed, the following table is inserted giving the yields of shelled corn per acre at thicknesses of planting ranging from one to five plants per hill, in hills 42 inches apart each way, for five different seasons, and the average of four seasons' tests. The year 1909 is omitted from the average since the shelling records are not yet available.

In these tests sufficient seed was planted that exact stands could be secured by thinning.

TABLE XVII: Continued. Average for four years, 1904, '06, '07, '08.

No. of plants per hill		Average weight of ears	Percent of		Yield of shelled corn per acre	Pounds stover per	
Hill	Acre		Nubbins	Barren plants		Acre	Bushels of corn
1	3,555	.68	10.3	2.2	31.47	2,484	78.9
2	7,110	.621	15.8	2.4	50.26	3,390	67.4
3	10,665	.545	19.5	4.0	59.28	3,994	67.4
4	14,220	.463	28.4	7.4	61.95	4,495	72.6
5	17,775	.402	39.8	11.8	60.29	4,969	82.4

It will be noted that the highest average yield of corn has been secured from four plants per hill, or 14,220 plants per acre. That five plants per hill have given a higher yield than three; however the average size of ears is much smaller and the percent of nubbins very large. For some uses this would be a disadvantage, but for shock feeding the small ears and the finer stover would be acceptable.

Very extensive tests with different distances between hills, and different numbers of plants per hill, have been conducted by the Illinois Experiment Station. The average of their large number of tests in six different localities in Illinois shows the highest yields to have been secured from an average stand of 11,107 plants per acre, and the second highest yields from 12,130 plants per acre.

Stands of 12,400 plants per acre may be had from three plants per hill, in hills 36x42 inches. With present information this may be regarded as perhaps a full stand for good soil conditions.

SUMMARY

While the tests herewith reported will be continued indefinitely, with some modifications, for the present they seem to show:

1. That the selection of seed ears of less than normal length, for a given variety or locality, will reduce the yield and, if the selection be continuous, gradually shorten the length of ear.

2. That shape of ear as regards cylindricity is a matter of le importance than many other of the prominent ear characters. Whi the tapering ears have, upon the average, led slightly in yield, th variation is neither important nor consistent, and more evidence needed before a pronouncement can be made for either type.

3. That the continuous selection of seed ears having an inch an inch and a half of bare cob at the tip will increase the averag amount of bare cob at the tip, diminish the total number of ea having completely filled tips, and decrease the yield of shelle corn per acre.

4. That so far as indentation of kernels is concerned, ears con paratively smooth—crease-dented—have proved somewhat superi in yield to the rough-dented ears.

5. That, conditions of growth being equal, weight of ear, made up of slight increases in length, circumference and amou and density of grain and cob, favors an increase in yield and worthy of consideration in the final selection of seed corn.

6. That a knowledge of the previous conditions of growth helpful in estimating the value of seed corn. And further, that see for use under given conditions would better be selected und slightly inferior, rather than a very much superior environment.

7. That the germination box can hardly be expected to pi out seed ears of superior hereditary merit. Its work is complete in atoning, in part, for carelessness in the handling of seed corn.

8. That the main crop of corn on every farm should be plante with varieties known to be productive and acclimated, and that in portations of seed corn from a distance should be confined to a ve limited area until, by careful selection, they have become adapted local conditions.

9. That a maximum yield of corn can hardly be secured und good soil conditions in this state with less than 12,000 plants p acre. This stand may be had with three plants per hill, in hills inches by 42 inches.

SPECIFIC EFFECTS OF RATIONS ON THE DEVELOPMENT OF SWINE

OHIO Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., DECEMBER, 1909

BULLETIN 213

The Bulletins of this Station are sent free to all residents of the State who request them. When a change of address is desired, both the old and the new address should be given. All correspondence should be addressed to EXPERIMENT STATION, Wooster, Ohio.

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The Bulletins of this Station are issued at irregular intervals. They are paged consecutively and an index is included with the Annual Report, which constitutes the final number of each yearly volume.

PREFACE

The feeding experiments on which this bulletin is based were conducted by the author at the Missouri Experiment Station in the years 1905 and 1906, and the results prepared for publication immediately thereafter.

The chemical data are principally the work of Dr. Paul Schweitzer, Dr. R. M. Bird and Mr. F. W. Liepsner, all of whom were connected with the Missouri Station at the time the work was done. The author acknowledges with much gratitude his indebtedness to these chemists, and also to Dr. C. W. Greene and Dr. W. Koch for courtesies enjoyed in their laboratories.

Certain additions to the chemical data are now made from the work of Mr. A. C. Whittier and the author, at the Ohio Experiment Station; the discussion is revised, and the bulletin is published at the Ohio Experiment Station, and issued simultaneously by the Missouri and Ohio stations.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 213. DECEMBER, 1909

SPECIFIC EFFECTS OF RATIONS ON THE DEVELOPMENT OF SWINE

By E. B. FORBES

INTRODUCTION

The characters of growing animals are determined by the limitations imposed by inheritance and the food supply. Inheritance furnishes detailed plans and specifications; food builds and maintains the structure.

Deficiences in the amount and kinds of nutriment available may affect not only the size, but also, within limits, the character of the growth of animals, just as shortage of certain building materials would affect the size and style of construction of a building.

The animal body is constructed from fourteen chemical elements. Not all foods contain all of these substances in amounts sufficient to sustain growth. Many of our by-product foods are abnormal and require knowledge and judgment in their use for animals; and Indian corn is, in a number of ways, deficient as a food for growing animals.

In the hands of stock breeders corn proves to be a poor producer of bone and muscle, and animals fed too little else along with their corn are apt to be lacking in size. The professional herdsman, and also many of the successful breeders of pure-bred stock of all kinds, believe that corn is injurious to breeding animals. We believe, however, that there is no time in the life of any farm animal in the Corn Belt when corn may not properly be used, whether it be with a fast horse or a slow one, a milch cow or a bacon hog, a laying hen or a breeding ewe; but for many purposes it must be used in moderation, and must be properly supplemented, so as to provide those nutrients in which it is deficient. Animals need energy-producing food, much more of it than of any other sort, and in this region corn will supply this kind of nutriment more cheaply than will any other food.

The specific effects of foods on growing animals appear to due very largely to the mineral elements which they contain.[1]

The influence of these constituents on the relative developme of fat, bone, muscle and visceral organs and on the qualitati composition of these tissues is, however, practically an unwork field, and appears to give promise of yielding much valuat information.

When the live-stock feeder shall have become thoroughly master of his business, he will know the specific or characterist effects of the foodstuffs which he uses, on the animals consumi them, just as the physician who is learned in therapeutics kno the specific actions of the drugs which he administers.

The fact that foodstuffs do have these specific effects on anim was demonstrated many years ago by J. W. Sanborn[2] of t Missouri Agricultural College. Subsequent work by Henry[3], a Shelton[4], along this same line confirmed Sanborn's conclusion, th rations containing more protein than does Indian corn produce mo muscular growth. These writers, however, made no mention the mineral constituents of the foodstuffs used.

In compounding the rations fed in these various experimen these authors apparently sought only to vary the proportions of t nitrogenous and non-nitrogenous organic nutrients without referen to mineral or ash constituents. It is true, however, that in the rations the nitrogenous and mineral constituents varied together that the high-protein rations happened also to be high in ash co stituents; hence there is hardly warrant for assuming that t proteid compounds alone are responsible for the effects observ on the relative development of fat and muscular tissue.

This above-mentioned work has been quantitative only, in so f as the various tissues are concerned, except in that Henry, Shelto Carlyle[5] and Burnett[6], have observed the fact that the ash consti uents of foodstuffs profoundly affect the ash content and breaki strength of the bones of hogs consuming them.

Numerous investigations, especially those of Shutt of Canad have also proven that the fat of hogs is susceptible of chemic modification through the use of ordinary foodstuffs.

In considering the significance of variations in the size of organ and the development of tissues, one should bear in mind that all the so-called vital organs together, including the nervous syste contain very much less substance than the remaining less essenti

[1] See Ohio Bul. 201, page 132.
[2] Bul. 10, 14, 19, Missouri Agricultural College.
[3] Annual Reports, Wis. Agr. Exp. Sta., 1886, '87, '88, '89.
[4] Bul. 9, Kans. Agr. Exp. Sta.
[5] Bul. 104, Wis. Agr. Exp. Sta.
[6] Bul. 94, 107, Neb. Agr. Exp. Sta.

parts; and rations which are so abnormal as to be inadequate to the necessities of these vital organs are very much more rare in practice than rations which would not contain sufficient nutriment, in excess of the demands of the vital organs, to support maximum development of the less essential parts. Hence it is especially in the development of the less essential fat, bones and muscles that we find the more noticeable specific effects of rations rather than in the development of the vital parts. These more important and carefully guarded vital organs are, of course, dependent in the end on the food supply just as are the less important ones which may serve them as stores of nutriment, and in especially compounded rations we have been able, in experiments at the Ohio Station, to modify even the chemical composition of the brain by withholding from the animal, phosphorus in the particular condition required by this organ.

These and other vital organs are maintained in condition to do their work, whether there be nutriment enough to support maximum development of the less essential organs or not; in fact, the wellbeing of the more important organs is maintained at the expense of the less important whenever insufficiency of nutrients makes this necessary. Thus fatty tissue is of less functional value to the animal than most others, and hence is sacrificed whenever the maintenance of more important tissues requires it. Muscular tissue also may be used up to such extent that the animal becomes much emaciated, in the maintenance of more important tissues in condition to perform their work.

The maintenance of the neutrality of the blood and tissues is of greater importance than the growth of the bones, and hence we find bony substance sacrificed whenever its carbonates are needed to neutralize a dangerous excess of mineral acid. In pregnant animals we find the same principle evidenced in the capacity of the foetus to rob the mother of any such nutriment as its development requires.

The size of the visceral organs is regulated, in part, in accordance with the principle that they take from the blood-stream such nutrients as they require to carry on the work imposed upon them. Departures from the average development in the directions either of increase or decrease may, therefore, be considered as partially determined by the amount of work which has been required of the organs in question, especially if these organs remain normal in composition, and partially by the capability of the food to cause gain of the sort required.

The following bulletin contains in addition to economic data, the beginning of a series of studies of the effects of foodstuffs on animals. It consists of the results from three experiments, the conclusions from the first beginning on page 266, and from the second and third on page 295. A general summary of results is to be found on pages 301 to 305.

EXPERIMENT I

Objects. The objects of this experiment were (1) to compare wheat middlings, linseed oil meal, soy beans, tankage and germ oil meal as supplements to corn in the dry-lot fattening of hogs for market; (2) to compare full-feeding on these rations with the feeding of restricted amounts; and (3) to observe the effects of these rations on the composition of the flesh.

Method of experimentation. This experiment was conducted during the months of April and May, 1905. There were in all sixty-five hogs used in this experiment. They were divided into thirteen lots of five each. One of these lots was killed at the beginning of the experiment and the carcasses were subjected to all the tests which were later applied to the hogs in the experiment proper, this lot constituting the check or basis of comparison for the lots which were fed.

These hogs were all grade Poland Chinas and were about seven months of age at the time the experiment began. They weighed about 120 pounds each and were in good, thrifty growing condition. All had run upon bluegrass pasture during the preceding winter, and had received nothing but corn and water in addition to the feed which they picked up. They were a uniform lot and were fairly good in quality. The same proportion of gilts and barrows was kept in each experimental lot. These hogs were fed in small pens with cement floors, the sheds sheltering them being open on the south. On account of the fact that these hogs had all received the same treatment before they went into this experiment, they were given only one week's preliminary feeding in the experimental sheds.

The first weights were taken on April 1, before the evening feed, and all subsequent weights were taken, as in this case, before giving the evening ration. With their first experimental feed they were given medicine for the purpose of expelling any such intestinal parasites as they might have with them. This procedure has been adopted as a standard method of operation in our feeding experiments, because we find that round-worms are so exceedingly common in swine that a feeding experiment undertaken with animals which have not been freed from these parasites is not at all certain to give accurate results. The dose administered in this case was

three grains of santonin and five grains of calomel for each 80 pounds of live weight. This has proven to be an especially effective remedy.

The hogs were fed twice daily, at regular times. All feed was ground into a moderately fine meal, and fed wet with water, until just thin enough to pour handily. Nothing in the way of ashes or charcoal was given to any lot, but salt was regularly administered with the grain, to the amount of one ounce per head per day. The hogs were watered regularly after feeding, and after the weather became warm, a third time at noon. The experiment progressed from start to finish without any accident or sickness to detract from the reliability of the results. The weather throughout the whole of the experiment was ideal for our purpose.

TABLE I: RATIONS USED

Lots	Rations	Amounts fed
1	Corn meal	Ad libitum.
2	Corn meal, 18.25 percent; wheat middlings, 81.75 percent	" "
3	Corn meal, 82.21 percent; linseed oil meal, 17.79 percent	" "
4	Corn meal, 80.43 percent; soy beans, 19.57 percent	" "
5	Corn meal, 91.94 percent; tankage, 8.06 percent	" "
6	Corn meal, 60.64 percent; germ oil meal, 39.36 percent	" "
7	Corn meal	" "
8	Corn meal, 18.25 percent; wheat middlings,, 81.75 percent	1.084 lbs. for each pound eaten by Lot 7.
9	Corn meal, 82.21 percent; linseed oil meal, 17.79 percent	1.0214 lbs. for each pound eaten by Lot 7.
10	Corn meal, 80.43 percent; soy beans, 19.57 percent	1.016 lbs. for each pound eaten by Lot 7.
11	Corn meal, 91.94 percent; tankage, 8.06 percent	1.016 lbs. for each pound eaten by Lot 7.
12	Corn meal, 60.64 percent; germ oil meal, 39.36 percent	1.01 lbs. for each pound eaten by Lot 7.
13	Check lot; killed at beginning of experiment.	

The nutritive ratio was the same, 1:6.5, in each case except where corn was fed alone as to Lots 1 and 7.

As will be seen by inspection of the above table, there were twelve lots of hogs fed in this experiment. The thirteenth lot, to which we shall refer throughout the bulletin as the "check lot," was killed just as the other twelve went on feed, this one furnishing us a basis for judgment as to the changes produced during the fattening process. Lots 1 to 6 were fed on the same rations as Lots 7 to 12, the only difference being that the first set were fed to the limit of their appetites, while in the second set each lot was given just such amount of feed as was necessary to provide the same number of pounds of digestible nutriment as was consumed by Lot 7, which

received corn alone, *ad libitum*. All of these rations, except consisting of corn meal alone, were so compounded that the nut ratio, or proportion of proteid to non-proteid organic nutri was as 1:6.5; hence it is seen that Lots 1 to 6 furnish us evider to the comparative usefulness of these rations as ordinarily while Lots 7 to 12 show us the comparative value of the amounts of digestible organic nutriment in the same nutritive but from different sources.

Corn meal was fed in both series as a standard ration. meal and wheat middlings were used in rations Nos. 2 and 8, be of the high esteem in which middlings is held by pork prod the country over. In order to get a ration having a nut ratio of 1:6.5, it was necessary to feed the middling larger proportion to corn than that in which we ordinarily us feed for profit.

Rations 3 and 9 are composed of corn and linseed oil me combination which we have found especially efficient and econo Rations 4 and 10 are composed of corn meal and soy beans. beans were used because they constitute the only concentr nitrogenous, grain supplement to corn which we commonly f profitable to produce on the farms of this region.

Rations 5 and 11 are composed of corn meal and dig tankage. This supplement has an advantage over many othe that its greater concentration renders it unnecessary that handled in such large quantities as the grain supplements. T age is dried and ground meat scrap, with most of the fat rem

Rations 6 and 12 are composed of corn meal and germ oil This supplement is a by-product from the manufacture of gl from corn. We used this feed in order to balance the corn with a corn product. This combination gives us an intere ration to compare with those in which the corn is balanced by stuffs produced by other plants.

TABLE II: CHEMICAL COMPOSITION OF FEEDS USED IN EXPERIMENT I

Feeds	Water	Protein Nx6.25	Nitrogen-free extract	Crude fiber	Ether extract	Ash	Phosphorus
	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Corn meal	15.87	8.06	69.06	1.92	3.64	1.45	.235
Wheat middlings	12.77	14 19	59.26	5.60	4.53	3.65	.901
Linseed oil meal	9.32	31.31	41.85	8.02	4.50	5.00	.81
Germ oil meal	10.50	19.69	49.27	8.52	9.17	2.85	.74
Soy beans	10.87	30.13	31.90	4.15	17.65	5.30	.745
Tankage	7.90	54.00	......	....	10.44	22.25	3.238

This table sets forth the chemical composition of the food stuffs used. It will be noted that the corn meal contained rather more moisture than this foodstuff usually carries in the spring. It was also rather low in protein and in fat. The wheat middlings was low in protein and high in fiber, ash and phosphorus. Its appearance and composition strongly suggested ground bran. The linseed oil meal was bought for the "old process" article, but the oil content was low. The germ oil meal was in every way typical of this by-product as usually found on the market. Its high oil content makes it necessary that it be fed with care, especially since it also necessitates its being fed in large proportion with corn, if used as a supplement to this feed. The soy beans were particularly rich in fat, and were also about as rich in protein as was linseed oil meal. The tankage contained 54 percent of protein. The carbohydrate material present was not determined. It will be observed that the ash content of the vegetable foodstuffs used ranged from 1.45 percent in corn meal to 5.3 percent in soy beans, but that the tankage contained 22.25 percent. Its high ash content was due largely to the fact that it contained a considerable amount of bone.

The lecithin content of these feeds was considered because of the interesting relation of lecithin to certain tissues in the body.

Lecithin is a wax-like substance composed of fat, glycero-phosphoric acid and a nitrogenous group called choline. It is found in all plant and animal cells, and its abundance in gland cells and in the germs of seeds, which contain great numbers of cell nuclei, suggests that it is a nuclear constituent. It is also abundant in the sexual elements, in eggs and in the nervous system. Its relation to living processes is apparently important, but its significance is as yet not understood.

Lecithin is a highly valuable nutrient, because of the wide range of its usefulness. Its importance as a constituent of the food depends on whether or not the animal can build up lecithin from other phosphorus compounds. This question is not yet finally settled.

TABLE III: DIGESTIBILITY OF FEEDS USED

Feeds	Number of trials	Dry matter	Protein (Nx6.25)	Crude fiber	Nitrogen-free extract	Ether extract	Authority
		Percent	Percent	Percent	Percent	Percent	
Corn	4	92.0	86.0	40.0	95.0	76.0	Wolff
Wheat middlings	2	76.5	76.2	48.2	86.2	94.5	Minn. Sta.
Linseed oil meal	2	77.5	86.0	12.0	85.0	80.0	Minn. Sta.
Germ oil meal*	4	92.0	86.0	40.0	95.0	76.0	Wolff
Soy beans**	1	81.9	91.1	71.2	76.3	85.7	Mass. Sta.
Tankage***			97.0			87.0	Wolff

* Assumed same as corn.
** Digestibility with sheep.
*** These coefficients determined for meat meal.

Our knowledge of the digestibility of even the commonest foodstuffs for swine is exceedingly scanty. We have assumed that the digestibility of the different nutrients in germ oil meal was the same as in the corn from which this foodstuff was made. The only digestion experiments with soy beans, known to us, were conducted with sheep at the Massachusetts Station, and these figures were used in this experiment. Since we had no digestion tests with tankage, we were obliged to assume that the protein and the ether extract in this feed have the same digestibility as in meat meal, upon which Wolff conducted a digestion experiment many years ago. Recent work by Dietrich of the Illinois Station indicates that the figure used for digestibility of protein in tankage is too high. The digestion coefficients which we have used for corn, were also determined by Wolff. The digestion coefficients of linseed oil meal and wheat middlings were made at the Minnesota Experiment Station.

Some of the assumptions above noted are unwarranted, and doubtless introduce errors into our work, but are believed not to be grossly misleading. Accuracy would have required that digestion experiments be conducted in connection with the test, but this was not possible.

TABLE IV: NUTRIENTS IN ONE HUNDRED POUNDS OF RATIONS AS COMPOUNDED

Lots	Feeds	Digestible protein	Digestible carbohydrates	Digestible ether extract	Phosphorus	Lecithin
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	Corn meal.........	6.93	66.37	2.77	.24	.11
2	Corn meal;........	1.26	12.11	.51	.04	.02
	wheat middlings...	8.84	43.97	3.50	.74	.60
	Total......	10.10	56.08	4.01	.78	.62
3	Corn meal;	5.70	54.56	2.28	.19	.09
	linseed oil meal....	4.79	6.50	.64	.15	.16
	Total......	10.49	61.06	2.92	.34	.25
4	Corn meal:........	5.57	53.38	2.23	.19	.09
	soy beans..........	5.37	5.34	2.96	.15	.36
	Total......	10.94	58.72	5.19	.34	.45
5	Corn meal;........	6.37	61.02	2.55	.22	.10
	tankage..........	4.22		.73	.26	.09
	Total......	10.59	61.02	3.28	.48	.19
6	Corn meal;........	4.20	40.25	1.68	.14	.07
	germ oil meal.....	6.66	19.76	2.74	.29	.41
	Total......	10.86	60.01	4.42	.43	.48

It must be borne in mind that the specific effects of each of these rations is dependent on the proportions in which the constituent foodstuffs are present. The characteristic effects of the rations containing wheat middlings and linseed oil meal, for instance, depend on the presence of these supplements in a particular proportion. Linseed oil meal contains considerably more lecithin than does wheat middlings, but the ration containing the oil meal contains very much less lecithin than the one containing the middlings; this because the oil meal was fed in so much smaller proportion to the corn than the middlings. Hence it is well to bear in mind that we are observing the characteristics, not of individual foodstuffs, nor of chemical compounds, but of *rations*. This gives an especial significance to Table IV, page 246.

The corn ration, compared with the others, is low in protein, in phosphorus and in lecithin, but high in carbohydrates.

The wheat middlings ration is the least concentrated of all, since it contains the highest percentage of indigestible fiber. It contains more phosphorus and lecithin than any other ration.

The remaining four rations are about equally concentrated, though the linseed oil meal and soy bean rations contain less phosphorus than the tankage and the germ oil meal rations. The soy bean ration also contains less starch and more fat than the tankage and the linseed oil meal rations.

The palatability of these rations is indicated by the amounts eaten by Lots 1-6. (Table V, page 248.) Many have considered corn to be more palatable to hogs than other foodstuffs, but these hogs ate less of the ration of corn alone than of any other except the ration of corn and germ oil meal. This last was a hard ration to feed. In general it was more palatable than corn, but after eating of it heartily for several days, the pigs would suddenly go off feed badly. It was hard to get their measure. The germ oil meal is bulky when wet, swelling through the absorption of a large amount of water. While it may be useful as a component of a more varied ration it was not satisfactory as a single supplement to corn.

It seems likely that the unsatisfactory character of this ration was due to the fact that all of its proteids came from corn.

Animals construct the proteids of their bodies from proteids only. The food proteids, however, cannot be built up into animal tissues until they have been split up into the primary nitrogenous groups from which they are composed, and then rearranged and reunited to form the particular compounds required by the animal.

TABLE V: TOTAL NUTRIENTS FED

Lots	Rations	Total feed consumed	Digestible protein	Digestible carbo-hydrates	Digestible ether extract	Phos-phorus	Lecithin
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	Corn meal...........	1292.5	89.57	875.83	35.80	3.04	1.44
2	Corn meal;.......... wheat middlings....	1456.5	147.13	816.77	58.33	11.35	9.09
3	Corn meal;.......... linseed oil meal......	1799.0	188.68	1098.50	52.50	6.09	4.62
4	Corn meal; .... soy beans............	1729.0	189.27	1015.27	89.73	5.78	7.73
5	Corn meal;.......... tankage.............	1786.0	189.20	1069.83	58.55	8.51	3.44
6	Corn meal; .... germ oil meal.......	1277.5	138.81	766.63	56.51	5.54	6.09
7	Corn meal....... ..	1306.5	90.54	867.12	36.19	3.07	1.45
8	Corn meal; .... wheat middlings. ...	1297.6	131.08	727.66	51.96	10.13	8.09
9	Corn meal; .... linseed oil meal......	1333.7	139.88	814.38	38.91	4.52	3.42
10	Corn meal; .... soy beans............	1327.5	145.32	779.51	68.89	4.44	5.93
11	Corn meal; .... tankage.............	1327.5	140.62	810.05	43.52	6.33	2.56
12	Corn meal; .... germ oil meal........	1258.5	136.75	755.22	56.66	5.46	6.00

It is easily conceivable that the proteids of corn should not contain these primary nitrogenous groups of the kinds and in the proportions most useful for the building up of the proteids of the hog's body.

The rations of mixed origin furnish a greater variety of plant proteins, from which the animal can select constituents more exactly suited to its particular needs.

The wheat middlings ration was eaten in larger quantity than the two above mentioned, but the hogs consuming this feed did not eat heartily and were easily forced off feed.

Recent experiments indicate that the unfavorable effects of wheat bran and middlings, when used in too large proportion to other feeds, are due to the excessive amounts of magnesium which they contain.

Mineral salts exercise a regulative function over a great number of the vital processes in animals. The maintenance of this control requires that the various salts be present in the liquids of the body in definite quantitative relation, one to another. (See Bul. 201, Ohio Agr. Exp. Sta.).

Magnesium and calcium salts appear to be antagonistic in their action, and the introduction of excessive quantities of magnesium salts into the circulation seems to result in the withdrawal of calcium from certain tissues, to protect others from the action of magnesium. The excess of both is then excreted.*

Thus the consumption of feeds like bran and middlings, which are characterized by very high magnesium contents, may cause a considerable loss of calcium from the body.

The failure of certain investigators to maintain hogs on wheat middlings alone, may be due to this factor, as may also be the existence of "bran disease", "shorts disease", or "miller's horse rickets" in horses.

The author has made considerable use of wheat bran as a food for brood sows, and has regarded it very highly. The above facts regarding the effects of an excess of magnesium in the body recall to mind, however, a number of sows which broke down while on this ration. Some recovered when the pigs were taken away. Others had to be killed. The indications are that an excess of magnesium and the consequent loss of calcium from the body, together with the removal of salts through lactation, were responsible for these troubles. The use of chalk in the ration, with the bran, would certainly have tended to alleviate the unfavorable symptoms.

At the close of the experiment the hogs receiving linseed oil meal were cleaning up their feed much better than any others. They were consuming feed in excess of their ability to digest it, as was shown by the appearance of undigested meal in the feces, but their appetites never faltered.

The linseed, soy bean and tankage rations were each eaten practically to the full limit of the capacity of the hogs, so that the differences in palatability are not fully shown by the figures. The oil meal ration was consumed much more rapidly after the sixty days full-feeding than either the tankage or the soy bean rations.

The wheat middlings ration contained much the most phosphorus and lecithin. Corn is low in both, but corn and soy beans together, make a ration which is rich in these constituents.

*Mendel and Benedict: Journ. Biol. Chem., Vol. 4, No. 2; Amer. Journ. Physiol., Vol. 25, No. 1.
Malcom: Journ. Physiol., Vol. 32, p. 182.
Meltzer and Auer: Amer. Journ. Physiol., Vol. 14, p. 366; Vol. 21, p. 400.
Forbes: Bul. 207, Ohio Agr. Exp. Sta., pp. 34, 37, 39, 44, 47.

The tankage ration, with its high content of bone, was rich phosphorus, but its lecithin content was low.

Lots 7-12, the limited ration series, were each to have been f the same amount of digestible nutriment, but our plans did n work out with absolute exactness. The wheat middlings and ger oil meal lots were so capricious in their appetites that they had be allowed the liberty of going their own gait, and they fell behi the standard.

The four other lots each received exactly the same number pounds of digestible nutriment, but when the non-nitrogenous co stituents were computed to "starch-equivalent", as in this table, t total amounts of nutriment no longer appear to be the same, b cause of the differences in the fat-content of the rations, fat havir a higher value than starch.

As the final results stand, however, we have a basis for a ve satisfactory comparison between the three most profitable ratio fed, those containing linseed oil meal, soy beans, and tankage, c two levels as to quantity.

TABLE VI: GAIN IN WEIGHT PER POUND DIGESTIBLE PROTEIN AND NON-NITROGENOUS STARCH-EQUIVALENT

Rations	Lot	Total nutriment consumed	Gain per pound nutriment	Lot	Total nutriment consumed	Gain per pound nutriment
		Lbs.	Lbs.		Lbs.	Lbs.
Corn..........................	1	1033.3	.265	7	1044.5	.275
Corn; wheat middlings....	2	1103.9	.344	8	983.4	.374
Corn; linseed oil meal......	3	1413.2	.356	9	1047.6	.364
Corn; soy beans...........	4	1419.9	.358	10	1090.2	.328
Corn; tankage.............	5	1419.6	.354	11	1055.2	.327
Corn; germ oil meal.....	6	1041.05	.306	12	1025.6	.314

In the full-fed series, Lots 1-6, the gain per pound of digestible nutriment was less with the corn lot than with any other; the corn and germ oil meal ration was also distinctly less efficient than the other mixed rations. The linseed oil meal, tankage, and soy bean rations were found to have almost exactly the same ability to cause gain in weight, while the wheat middlings ration was less efficient in this regard.

In the limited ration series, Lots 7-12, the rations of corn, and of corn and germ oil meal, proved again to be less efficient than the others. The higher relative efficiency of the wheat middlings, and linseed oil meal rations in this series, if these figures represent the actual facts, would lead us to the conclusion that they have a use-

fulness which is due to factors which are as yet obscure. It is possible that the high phosphorus content of the middlings ration was an advantage, and that its high fiber content helped to satisfy the pigs. During most of the experiment this lot was really fed *ad libitum*. The linseed oil meal, soy bean and tankage lots suffered from a constant affliction of appetite, which may have retarded their fattening.

Too close a comparison should not be drawn between the results in these two series, because the two rows of pens were not exactly alike, there being slightly more sunshine in the pens of the limited ration series. The corn straight, the wheat middlings, and the germ oil meal rations, which were really fed *ad libitum* in both series, were all slightly more efficient in the second one.

It is impossible to make a statement of the financial outcome of such a comparison of feeds, which will be at the same time useful and true. The reason is that market conditions are never the same at two different times, or in two different places. The relative prices of feeds today, in any given market, do not apply in any other market, and in all probability will never again recur.

We would suggest that the cost of pork made from these rations be calculated as follows, using such prices for feeds as prevail at the time and place of interest.

Suppose corn meal to cost 56 cents per bushel, linseed oil meal $30.00 per ton, and tankage $40.00 per ton; or corn 1 cent per pound, oil meal 1.5 cents per pound and tankage 2 cents per pound. (See Table VII, page 252.)

With Lot 1 it took 471.7 pounds of corn to make 100 pounds of pork. At 1 cent per pound this corn would cost $4.72. With Lot 3, receiving corn meal and linseed oil meal, there were required to produce 100 pounds of pork, 357.6 pounds of feed, of which 17.79 percent or 63.62 pounds were oil meal, (cost $63.62 \times 1.5 = 95.4$ cents), and 82.21 percent,or 293.98 pounds were corn, (cost $2.94). Adding these two costs, $0.95 and $2.94, we find that 100 pounds of pork cost $3.89.

With Lot 5, receiving corn meal and tankage, there were required 355.8 pounds of feed to make 100 pounds of pork. Of this feed, 91.94 percent, or 327.12 pounds, were corn—cost $3.27; while 8.06 percent, or 28.68 pounds, were tankage—cost $0.57. Adding these costs of corn and tankage, $3.27+.57=$3.84, the cost of 100 pounds of pork with this ration.

In considering the replacement values of the supplements, as set forth in the fourth, fifth and sixth columns of figures in Table VII, it is necessary to bear in mind the fact that pork is not

TABLE VII: FEED CONSUMED, GAINS IN WEIGHT, AND VALUATION OF SUPPLEMENTS

Lots	Rations	Grain per cwt. gain	Average daily gain	Average daily feed	Values per ton of supplements corresponding to values of corn			Average initial weight	Average final weight
					Corn $ .40 bu.	Corn $ .50 bu.	Corn $ .60 bu.		
		Lbs.	Lbs.	Lbs.				Lbs.	Lbs.
	Series A. Ad libitum								
1	Corn meal	471.7	.91	4.31				114.2	169.0
2	Corn meal, 18.25 percent; wheat middlings, 81.75 percent	383.3	1.27	4.85	$19.92	$22.40	$26.87	117.4	193.4
3	Corn meal, 82.21 percent; linseed oil meal, 17.79 percent	357.6	1.68	6.00	37.98	47.47	56.90	119.8	220.2
4	Corn meal, 80.43 percent; soy beans, 19.57 percent	340.4	1.69	5.76	40.56	50.73	60.94	118.6	220.2
5	Corn meal, 91.94 percent; tankage, 8.06 percent	355.8	1.67	5.95	67.73	84.38	101.82	116.6	217.0
6	Corn meal, 60.64 percent; germ oil meal, 39.36 percent	401.1	1.06	4.26	19.90	24.84	29.90	120.1	183.8
	Series B. Limited quantity								
7	Corn meal	454.5	.96	4.35				119.5	177.0
8	Corn meal, 18.25 percent; wheat middlings, 81.75 percent	352.6	1.23	4.32	$19.76	$24.70	$29.63	121.0	194.6
9	Corn meal, 82.21 percent; linseed oil meal, 17.79 percent	350.1	1.27	4.44	40.20	50.42	60.38	120.0	196.2
10	Corn meal, 80.43 percent; soy beans, 19.57 percent	370.8	1.19	4.43	32.46	40.52	48.78	120.0	191.6
11	Corn meal, 91.94 percent; tankage, 8.06 percent	384.8	1.15	4.43	50.35	62.92	75.44	116.6	185.6
12	Corn meal, 60.64 percent; germ oil meal, 39.36 percent	390.5	1.07	4.16	21.02	26.28	31.48	120.6	185.0

cessarily made most cheaply by the use of the supplement having highest replacement value, as was demonstrated by the author Missouri Bulletin No. 65.

Consider, for instance, the above computation of the cost of rk. The cost is practically the same where linseed oil meal, and iere tankage are used, even though tankage has a very much ;her replacement value than linseed oil meal, as is shown in Table I, on page 252. This is due to the higher cost of tankage, and smaller percentage of tankage used to balance the ration.

Comparing corn alone with the supplemented rations, we find at the linseed, tankage, and soy bean rations made about 85 per- nt more gain in the same time. The longer the feed, the greater the loss of possible profit by feeding corn by itself.

The wheat middlings rations were more efficient than corn ne, the gain being greater, and the feed required being less. It ist be borne in mind, however, that the character of the increase s very different in these two cases. The middlings hogs grew, t did not fatten much. The corn-fed hogs were perceptibly aller, but fatter. The middlings hogs had conspicuously heavy ts of hair.

The fourth, fifth and sixth columns of figures state the costs the supplements at which it would be an even thing whether they used with the corn or not. If the supplements can be purchased prices less than those stated, they will return a profit; otherwise t.

As corn varies in price between 40 and 60 cents per bushel, ieat middlings may be valued between $19.92 and $26.87 per ton; at is, to make it an even thing whether the middlings be used with corn, or the corn be fed alone.

In the same way linseed oil meal varies in value, in terms of rn saved by its use, between $37.98 and $50.90 per ton; soy beans tween $40.56 and $60.94 per ton; tankage between $67.73 and 01.82 per ton, and germ oil meal between $19.90 and $29.90 per n.

The linseed oil meal, soy bean and tankage rations returned very tisfactory profits, and each produced gains in weight of about 1.7 unds per head, per day, at about the same expenditure of feed. hese foodstuffs will still return a profit at considerably increased st, as is indicated by the valuations in the fourth, fifth and sixth lumns of figures.

The soy bean has the advantage of being capable of successful me production. This test shows it to be particularly valuable as hog feed. The method of this experiment furnishes a very satis-

factory comparison between this feed and the others used, but for profit we would doubtless use another system. For fall feeding the beans may be "hogged off", corn being fed in addition, and the hogs being restricted as to range over the field, by a movable fence. For winter feeding the beans may be cut a little early, cured as hay, and fed as a supplement to corn, without preparation.

The germ oil meal lots were a disappointment. This corn product seems not to be the proper thing to use as a supplement to corn; other feeds are better adapted to this purpose. The ration was neither cheap, nor efficient, nor palatable, and the gains made were not large.

The linseed oil meal, soy bean, and tankage hogs were much fatter than the corn and middlings lots. The linseed oil meal hogs graded "prime" in condition, and possessed that uniformly high finish which has made this feed a favorite with breeders of fine stock. The soy bean and tankage lots were graded "choice", being not quite so fat nor so uniformly fat as the linseed lot. The germ oil meal lot graded "good," was fatter than either the corn or the middlings hogs, and ranked ahead of the corn lot, but much behind the middlings lot in apparent growth of frame.

From the limited ration series, Lots 7-12, we may draw this practical conclusion: The less gain a hog is making, the more nearly does corn become a perfect food, and the less will be the profit from the use of nitrogenous supplements. Large consumption of feed and large gains in weight are essential to the most profitable use of supplementary feeds. Corn is more rich in protein than is necessary in a mere maintenance ration, but the further we get from the maintenance ration, that is, the more flesh we produce in a given time, the less efficient is corn alone, and the greater is the need of supplements. This principle receives constant recognition from dairymen, who know that the more milk a cow produces, the narrower must be her ration, but we do not happen to have seen the point mentioned in connection with meat production. It is, of course, so obviously true as to need no proof.

After the completion of the feeding test, the sixty hogs were shipped to a small packing-house at Alton, Illinois, where arrangements had been made for the killing.

After the hogs were dressed, the carcasses were cooled, and the tenderloin muscles dissected out, weighed and placed in screw-top bottles with rubber rings to prevent evaporation.

A cross-section taking in the sixth rib was procured from each hog. Each cross-section, as cut out, was wrapped in parchment paper, to prevent evaporation, until it could be sampled for analysis.

TABLE VIII: AVERAGE SLAUGHTER WEIGHTS

Lot	Rations	Live-weight	Gross dressed weight	Leaf-lard	Kidneys	Heads and jowls	Lungs	Heart	Liver	Spleen	Tender-loin muscles*	Percent dressed to live weight**
		Lbs.	Lbs	Lbs.	Ozs.	Lbs.	Lbs.	Ozs.	Lbs.	Ozs.	Ozs.	
1	Corn	173.8	132.8	4.61	6.15	13.03	1.78	8.38	2.78	3.10	5.43	76.4
2	Corn; wheat middlings	196.0	146.0	3.92	8 60	13.70	2.63	10.03	3.74	3.83	7.63	74.5
3	Corn; linseed oil meal	225.6	175.1	5.85	8.65	15.94	2.40	10.83	3.83	4.05	7.10	77.6
4	Corn; soy beans	223.8	174.0	6.34	8.68	16.29	2.19	10.13	3.89	3.78	6.68	77.7
5	Corn; tankage	223.6	173.0	6.47	8.13	16.00	1.96	10.20	3.64	3.35	6.53	77.4
6	Corn; germ oil meal	190.2	143.7	4.84	7.03	13.39	2.39	9.00	3.24	3.25	6.44	75.6
7	Corn	183.2	141.2	6.48	6.95	13.06	1.61	8.20	2.94	2.53	4.78	77.1
8	Corn; wheat middlings	198.2	146.2	4.00	8.70	13.88	2.24	10.03	3.71	3.70	6.85	73.8
9	Corn; linseed oil meal	203.6	156.4	5.12	7.53	13.81	1.80	10.30	3.56	3.58	6.78	76.8
10	Corn; soy beans	196.0	152.6	5.07	8.78	14.54	2.16	10.18	3.76	3.35	6.08	77.8
11	Corn; tankage	194.4	150.5	4.82	7.13	14.44	1.64	9.70	3.40	3.02	6.15	77.4
12	Corn; germ oil meal	192.4	143.5	4.17	7.75	14 09	1.80	8.95	3.40	3.23	6.75	74.6
13	Check lot	120.6	87.5	2.29	5.21	6.75	1.13	7.25	2.46	2.78	4.61	72.6

* Weight of one muscle. ** At Columbia.

In preparing them for sampling, the skin and bones were removed, and the remainder repeatedly run through a sausage mill so that the parts might be well mixed. Composite samples were prepared from each lot of five pigs, and after much grinding and mixing were put into small bottles, packed in an ice-cream packer, and expressed to Columbia for analysis. The tenderloins were similarly treated.

As the carcasses were being cut up, each was examined by the superintendent of the packing plant. None were found objectionably soft. The linseed oil meal hogs were characterized by conspicuous thickness, firmness, and especially evenness, of the covering of fat. The butchers learned in a very few minutes to pick out those that had received oil meal, by their marked excellence. They were especially interested because it had been their belief that this feed produced soft pork.

The soy bean hogs were slightly less firm than the linseed oil meal hogs, but not objectionably so. The tankage hogs also occasioned favorable comment.

In general, those hogs which were least fat were least firm in the fat. This explains the fact that the middlings hogs were the softest, they being the least fat. A middlings-fed hog that is finished has an unexcelled, brittle hardness of fat.

The germ oil meal hogs were also too backward in condition to appear to especial advantage. The most noticeable thing about the cutting, however, was the relative development of fat and lean in the carcasses. Every hog which was conspicuous for the thickness of its lean meat came from a wheat middlings lot. The characteristic of the corn-fed hogs was that these appeared to have deposited much fat within the lean, but were not especially thick in either fat or lean.

The linseed oil meal, and soy bean hogs had the appearance of having both grown and fattened, neither function predominating to a noticeable extent.

These hogs, weighing about 120 pounds at the beginning of the experiment, were fed out in sixty days, the best of them to good fat-hog weights, as is seen in the first column of figures in Table VIII, page 255.

The last column gives the percentage of dressed to live-weight. The lack of proper scales at the packing house made it necessary that we base this figure on our Columbia weights, hence the hogs appear to have dressed a low percentage of carcass.

In the full-fed series, Lots 1 to 6, the linseed, soy bean and tankage lots outdressed the corn lot in spite of having heavier waste parts. They were decidedly fatter.

In the limited ration series, Lots 7 to 12, the soy bean and tank-e lots outdressed the corn lot, while in both series the wheat ddlings lot ranked last as to percentage of dressed to live-weight. ney had fattened very little and their offal parts were well veloped.

These weights of parts are here set down to give them perman-t record, but their true significance is not manifest in this form; e next three tables being so computed as to set forth their real efulness.

In both series, (Table IX, page 258), the corn lots yielded the lowest rcentage of net to gross dressed weight, while the middlings lots each series yielded the highest percentage, followed in each case the linseed oil meal lot. The net dressed weight is the gross essed weight minus the head, leaf-lard and kidneys, and in some tablishments, the ham facings. It represents the hog as sent to e cooler. If in the development of the hog, the head and the leaf-d should fall behind the muscular system in rate of increase, we uld have an increased percentage of net to gross dressed weight. is is just what took place in the middlings lots. Thickness flesh, whether it be due either to development of fat or muscle, nds to increase the percentage of net to gross dressed weight. is is of importance to the packer, since the net dressed weight worth more per pound than the gross dressed weight.

The percentage of leaf-lard is a good indication of the develop-ent of the internal fat generally. An abundance of internal fat in og is much in the packer's interest, but is not an advantage to a eeding animal on the farm. Pressure of internal fat upon repro-ctive and other vital organs cannot fail to operate disadvan-geously, through impairment of the circulation of the blood in ose parts.

The largest proportion of kidneys, lungs, heart, liver and spleen ere in both series found in the wheat middlings lot. This is rtially due to the fact that these hogs were not fat, but largely so to the fact that these parts were well developed, as will be parent from an inspection of Table VIII, page 255. The lungs of e middlings lots, Nos. 2 and 8, were both relatively and absolutely rger than any others. The tenderloin muscles were also large, in ot 2 being both relatively and absolutely larger than in any other t, while in Lot 8 they were absolutely heavier than any other in the cond series, but relatively not heavier than in the germ oil meal t. The only difference known to exist between the middlings ra-ons and those fed to the other lots, which might account for this re-arkable showing, is in the phosphorus content, the middlings rations eing especially rich in easily assimilable phosphorus compounds.

TABLE IX: RELATION OF DIFFERENT PARTS TO DRESSED CARCASS

Lot	Ration	Percent net to gross dressed weight	Percent leaf-lard	Percent kidneys	Percent head and jowl	Percent lungs	Percent heart	Percent liver	Percent spleen	Percent tenderloin
1	Corn	86.4	3.47	.290	9.81	1.34	.394	2.09	.146	.255
2	Corn; wheat middlings	87.6	2.69	.368	9.38	1.80	.430	2.56	.164	.327
3	Corn; linseed oil meal	87.2	3.34	.309	9.10	1.37	.387	2.19	.144	.254
4	Corn; soy beans	86.7	3.64	.312	9.36	1.26	.364	2.24	.136	.240
5	Corn; tankage	86.7	3.73	.294	9.24	1.13	.367	2.10	.121	.236
6	Corn; germ oil meal	87.0	3.43	.242	9.32	1.66	.391	2.25	.141	.280
7	Corn	85.9	4.59	.308	9.25	1.14	.363	2.08	.112	.211
8	Corn; wheat middlings	88.8	2.73	.372	9.49	1.53	.428	2.54	.156	.293
9	Corn; linseed oil meal	87.6	3.27	.301	8.83	1.15	.412	2.28	.143	.271
10	Corn; soy beans	86.8	3.32	.359	9.54	1.42	.417	2.46	.137	.249
11	Corn; tankage	86.9	3.13	.296	9.59	1.09	.403	2.26	.158	.255
12	Corn; germ oil meal	87.0	2.90	.338	9.82	1.25	.390	2.37	.125	.294
13	Check lot	89.3	2.62	.475	7.71	1.29	.516	2.81	.140	.329

: is interesting to note that in Lot 13, the check lot, which was at the beginning of the experiment, the percentages of kidneys, , liver, spleen and tenderloin muscle were all larger than in any other lots after sixty days' feeding. The lungs, however, in ıber of cases were relatively heavier in the fattened hogs than s check lot.

TABLE X: PERCENT OF INCREASE IN LIVE WEIGHT AND IN CERTAIN PARTS AND ORGANS

Rations	Live-weight	Leaf-lard	Kid-neys	Lungs	Heart	Liver	Spleen	Tender-loins
Corn................	52.2	112.4	24.74	66.4	22.16	19.31	17.87	24.31
Corn;wheat middl'gs.	67.0	75.8	69.62	139.1	42.07	56.49	41.32	70.31
Corn; linseed oil meal	88.3	156.6	66.99	114.3	50.42	56.97	46.73	55.02
Corn; soy beans......	88.7	181.8	69.53	97.3	42.08	60.74	38.46	47.46
Corn; tankage.......	91.8	191.4	61.31	79.8	45.51	52.94	24.53	46.74
Corn; germ oil meal.	58.4	112.3	35.45	111.5	24.65	32.24	17.32	40.30
Corn................	53.3	185.5	34.69	43.8	14.21	20.49	—8.00	4.82
Corn; wheat midd'gs	63.8	74.0	66.35	98.2	37.96	50.20	32.61	48.26
Corn;linseed oil meal	69.7	124.0	45.37	60.7	42.86	45.30	29.24	48.03
Corn; soy beans.....	63.3	122.4	69.50	92.9	41.19	53.46	20.93	32.75
Corn; tankage.......	66.7	117.1	41.47	50.5	38.37	42.85	8.63	38.20
Corn; germ oil meal.	59.5	82.1	48.75	59.3	23.45	38.21	16.19	46.42

n the sixty days of this experiment these 120-pound hogs ased in weight to the extent of 52-92 percent, according to the nt and kind of feed. Corn alone produced the smallest per- ge of increase. The rations containing linseed oil meal, soy s and tankage, in the full-fed series, produced practically the percentage of increase in weight. They received the same nt of nutriment, (Table VI, page 250), and hence gained with efficiency. This gives us an excellent opportunity to judge of ifference in the kind of gain produced by these rations. The in leaf-lard differed considerably, the tankage ration being first, soy bean ration being second, and the linseed oil meal ration . The gain in tenderloin muscles also differed, but here the · of these three lots was just reversed, the linseed ration seem- o produce the most growth, the soy bean ration next, and the ge ration last. The tankage ration contained the most corn. e three lots gained in lungs and in spleen in the same relative · as in the tenderloin muscles; that is, linseed oil meal first, soy s second, and tankage third.

The wheat middlings ration, No. 2, with much less gain in weight, gained very much more than the linseed oil meal, soy or tankage rations, in weight of tenderloin muscle. This ra excels all others in this regard in both series. In the full-fed se the middlings lot excelled all others in the gain made in kidneys lungs, as well as in the tenderloin muscles.

The germ oil meal lot, No. 6, would appear from the increas the leaf-lard, not to have fattened much better than the corn lot, the additional protein caused a markedly greater increase in kidn lungs, liver and tenderloin muscles in this germ oil meal lot tha the corn lot, No. 1.

The corn lot seems to have made the least increase of all in weight, kidneys, lungs, heart, liver, and tenderloin muscles. T observations are true in both series.

In the second, or limited ration series, Nos. 7-12, the c and the germ oil meal rations produced the least gain in weight. this series the best comparisons may be made between Lots 7, and 11, since they received very nearly the same amounts of n ment, as is seen in Table VI, page 250.

The corn lot, No. 7 in this series, gained much more in leaf- than other lots. It was last of all, however, in increase of e other part observed.

The kidneys and livers of the soy bean lot excelled other gain in weight, while in the middlings lot the lungs and tender muscles were heavier than in other lots.

The data in this table have reference to the gain in each or by itself, independent of all else. In the following table, No. page 261, the gain in these organs is in each case referred to gain in live weight, so that we are able to say that for each per of gain in live-weight of the animal, each of these organs increas certain part of one percent of its own weight. In case the an were developing just symmetrically in all parts, the percent of in each one of these portions would be the same as in live-wei The departures from this order are interesting and significant.

This table, more than any other, exhibits the real spe influence of these rations. In both series the corn lot gained in lard much more rapidly than in live-weight, and also gained relati more in leaf-lard than any other lot. In all other parts except lungs, the gain, relative to gain in weight of these corn fed hog very low. It is probably more than a coincidence that the lungs leaf-lard should exceed other parts in proportionate gain. T observations refer us to the two methods of disposal of the ex non-nitrogenous starch-equivalent which was present in the ratio

iese corn-fed hogs. They must lay it onto the body as fat, or work off through the lungs as carbon-dioxide. These hogs in close con-iement seem to have disposed of it largely by making it into fat; fact, nearly all of these hogs, ten out of the twelve lots, gained in af-lard more rapidly than in live-weight or in any other part oserved. In the two middlings lots, and in these alone, the relative in in lungs was greater than in leaf-lard. In no one of the twelve ts is the gain in any other part observed as great in relation to in in live-weight as in leaf-lard and lungs.

TABLE XI: INCREASE IN WEIGHT OF VARIOUS PARTS AND ORGANS IN RELATION TO GAIN IN LIVE WEIGHT

ots	Rations	Leaf-lard	Kid-neys	Lungs	Heart	Liver	Spleen	Tenderloin
1	Corn	2.15	.47	1.27	.425	.370	.342	.47
2	Corn; wheat middlings	1.13	1.04	2.08	.628	.843	.617	1.05
3	Corn; linseed oil meal	1.77	.76	1.29	.571	.645	.529	.62
4	Corn; soy beans	2.05	.78	1.10	.474	.685	.434	.54
5	Corn; tankage	2.08	.69	.87	.495	.577	.267	.51
6	Corn; germ oil meal	1.92	.61	1.91	.422	.552	.296	.69
7	Corn;	3.48	.65	.82	.267	.384	—.150	.09
8	Corn; wheat middlings	1.16	1.04	1.54	.600	.787	.511	.76
9	Corn; linseed oil meal	1.78	.65	.87	.615	.650	.420	.69
0	Corn; soy beans	1.93	1.10	1.47	.651	.845	.331	.52
1	Corn; tankage	1.75	.62	.76	.575	.642	.129	.57
2	Corn; germ oil meal	1.38	.82	1.00	.394	.642	.272	.78

In each one of the twelve lots it is true that the relative gain of e spleen is less than that of any other part observed. Its function the body seems to be fulfilled without so much increase in weight occurs in these other organs.

The wheat middlings lots developed kidneys, lungs and tender-in muscles to a greater extent than other parts.

In both series the corn, tankage and germ oil meal rations produced uch smaller relative gains in weight of spleen than did other rations. hese three rations are the ones made up most largely of corn.

TABLE XII: RELATION OF GROWTH TO INCREASED WEIGHT OF LEAF-LARD

ot	Rations	Leaf-lard	Lungs	Spleen	Kid-neys	Heart	Liver	Tender-loin	Phos-phorus Lbs.
2	Corn; middlings	1.13	2.08	.617	1.04	.628	.843	1.05	11.35
3	Corn; linseed oil meal	1.77	1.29	.529	.76	.571	.645	.62	6.09
4	Corn; soy beans	2.05	1.10	.434	.78	.474	.685	.54	5.78
5	Corn; tankage	2.08	.87	.267	.69	.495	.577	.51	8.51
1	Corn	2.15	1.27	.342	.47	.425	.370	.47	3.04

Arranging as above, Lots 1 and 5, from Table XI, page 261 we place them almost in order of relative gain in weight of tenderloin muscles, liver, heart, kidneys, spleen, lungs and the amount of phosphorus in the rations, and inversely as the relative gain in leaf-lard. In so doing we display the relative tendencies of these rations to cause growth and fattening. The observations made on the germ oil meal lot do not conform so closely to this order.

We beg to repeat, however, that these characteristics are not of the supplementary foodstuffs, but of the rations. It is of importance that this distinction be noted. The relative efficiency would certainly have been very different if these rations had been made up of the same foodstuffs in other proportions. It is a fair comparison, however, in the sense that these rations were as nearly as we could get them of the same proportionate content of digestible protein and non-nitrogenous starch-equivalent.

The tankage ration does not cause growth to an extent proportional to its phosphorus content, because its phosphorus is so largely in the shape of bone, the inorganic phosphorus of which appears to be limited as to usefulness.

In the second series the same tendencies are manifest, but the agreement is less orderly. These results are at best hardly more than suggestive since the method of work was necessarily crude under the conditions existing.

TABLE XIII: RELATION OF PHOSPHORUS TO DEVELOPMENT OF MUSCLE

Lot	Rations	Total phosphorus consumed	Total gain in weight of lot	Gain in weight of muscle of lot	Total lecithin consumed	Fat in muscle
		Grams	Lbs.	Percent	Grams	Percent
2	Corn; wheat middlings	5149.3	380	70.2	4123.2	5.04
5	Corn; tankage	3862.4	502	46.6	1560.4	5.17
3	Corn; linseed oil meal	2762.9	503	56.1	2095.6	4.01
4	Corn; soy beans	2624.1	508	47.3	3506.3	4.79
6	Corn; germ oil meal	2512.5	318.5	40.3	2762.4	4.67
1	Corn	1377.6	274	24.4	653.2	7.28
8	Corn; wheat middlings	4587.3	368	48.3	3669 6	4.54
11	Corn; tankage	2870.8	345	38.2	1161.2	3.92
12	Corn; germ oil meal	2475.3	322	46.4	2721.6	4.31
9	Corn; linseed oil meal	2048.5	381	47.9	1551.3	5.57
10	Corn; soy beans	2015.8	358	32.6	2689.8	3.21
7	Corn	1392.6	287.5	4.7	657.7	8.29

This table shows both series arranged according to the phos-
rus content of the total feed administered. There is no apparent
nection between the phosphorus content of these rations and the
in live-weight; nor between the phosphorus content and the per-
of fat in the muscle; neither does the lecithin content of the
n seem to be closely in accord with these other items noted, but
phosphorus content in each series does correspond somewhat
itely with the gain in the weight of the tenderloin muscles,
cially when we consider the fact that as previously observed,
age carries its phosphorus mostly as bone. It is not impossible
the significant connection between the gain in muscles and the
position of the ration, should be between these organs and some
constituent or characteristic of the ration, which varies directly
e phosphorus. The probability, of course, is that this is an
ntial connection; that the phosphorus is used as a nutrient, and
at least those rations containing less phosphorus than the
llings rations do not contain as much of this element as is
ssary to maximum muscular growth.

TABLE XIV: ANALYSIS OF TENDERLOIN MUSCLES

Rations	Water	Protein	Fat	Ash	Water in fat-free meat	Fat in water-free meat	Ash in fat- and water-free meat
	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Corn	71.55	19.187	7.28	1.1076	77.38	25.77	5.282
Corn; wheat middlings	72.94	20.675	5.04	1.1505	76.81	18.62	5.225
Corn; linseed oil meal	74.08	20.506	4.01	1.1790	77.17	15.47	5.381
Corn; soy beans	72.91	20.944	4.79	1.1228	76.58	17.68	5.035
Corn; tankage	73.66	19.783	5.17	1.1280	77.68	19.63	5.328
Corn; germ oil meal	73.53	20.549	4.67	1.0760	77.13	17.64	4.936
Corn	71.52	19.033	8.29	1.0630	77.98	29 05	5.265
Corn; wheat middlings	73.58	20.581	4.54	1.1040	77.08	17.18	5.046
Corn; linseed oil meal	72.56	20.456	5.57	1.1750	76.84	20.29	5.373
Corn; soy beans	74.14	21.224	3.21	1.1320	76.60	12.41	4.998
Corn; tankage	73.93	20.593	3.92	1.1070	76.95	15.03	4.998
Corn; germ oil meal	74.17	20.196	4.31	1.0540	77.51	16.69	4.898
Check lot	73.53	19.926	4.61	1.1041	77.81	17.42	5.051

In both series the muscles of the germ oil meal lots have less
and the muscles of the linseed oil meal lots have more ash than
und in any other lots. These observations are true when the
entage of ash is computed, either on the basis of the meat as a
e, or on the fat- and water-free meat.

It is also worthy of note that in both series the corn lot ran ahead of the middlings, soy bean, and germ oil meal lots as rega the percentage of ash in the fat- and water-free meat, though on basis of the meat as a whole, the ash is low in the corn lots, beca of the high percent of fat.

The percent of fat in the water-free meat shows the corn to have had much the fattest muscles; that is, more fat was posited within the muscles than in other lots. This is of importa as indicating the quality of the flesh from a culinary standpoint, intimate intermingling of fat and lean being considered essential the highest quality.

The lower percentages of fat and the higher percentages water were usually found associated. This would be expected arithmetical grounds. When we compute the percentage of wa in the fat-free meat, however, factors other than arithmetical o seem to be operative. The percentage of water in the fat-free m of the corn lots was high in both series.

The tendencies of corn to deposit fat within the muscles, a to restrict the development of the nitrogenous tissues, as is pro by the small muscles of the corn-fed hogs, are probably due to fact that corn furnishes to the muscles more carbohydrate food t they have occasion to oxidize in the production of energy, it bei therefore, of necessity, deposited as fat; and further, to the fact t corn is probably lacking in the amount both of protein and ph phorus requisite to maximum muscular growth of a nor composition.

During this experiment these hogs, except in the corn l were receiving much narrower and more nearly normal rations t the one on which they had been raised. They were really corn- when the experiment began. It is interesting to note in c paring the check lot with some others that were fed for sixty da that the change in feed, together with the increase in age, redu the percentage of water in the fat-free meat even where it also duced the precentage of fat in the meat.

The linseed oil meal ration, in the full-fed series, produ muscles that contained more water and ash, and less fat, than found in any other lot. The fact of this low fat- and high wa content is difficult to explain. It seems not to have been due fault in this sample, because the water in the fat-free meat of cross-sections in the same series was also high; but in the limi ration series the oil meal lots, both with the muscles and the cr sections, were characterized by a high fat content, and low p centage of moisture in the fat-free meat. The high proportion ash to protein, however, holds in both samples of meat and b series, and so may be considered as characteristic of this ration.

TABLE XV: ANALYSIS OF THE MEAT OF THE CROSS-SECTIONS OF THE CARCASS.

Rations	Water	Protein	Fat	Ash	Water in fat-free meat	Fat in water-free meat	Ash in fat- and water-free meat
	Percent	Percent	Percent	Percent	Percent	Percent	Percent
rn	32.13	7.944	59.53	.422	79.39	87.71	5 060
rn; wheat middlings	36.44	8.940	53.33	.460	78.08	83.90	4.497
rn; linseed oil meal .	28.48	7.459	63.72	.391	78.50	89.09	5.013
rn; soy beans.......	28.19	7.754	63.36	.407	76.94	88.23	4.817
rn; tankage.........	29.55	7.635	62.75	.341	77.25	89.07	4.429
rn; germ oil meal...	33.81	9.060	56.99	.395	78.61	86.10	4.350
rn	28.51	7.010	63.94	.375	79.06	89.44	4.967
rn; wheat middlings	32.95	8.623	57.77	.463	78.02	86.16	4.989
rn; linseed oil meal..	29.77	7.947	61.97	.418	76.27	88.24	5.061
rn; soy beans......	36.90	9.644	52.66	.496	77.94	83.45	4.751
rn; tankage.........	33.40	8.862	56.92	.454	77.53	85.47	4.690
rn; germ oil meal..	34.76	9.307	55.05	.538	77.33	84.38	5.280
eck lot............	43.55	11.929	42.80	.726	77.13	75.82	5.322

he sampling of the meat of the cross-sections, difficulties ncountered which were not satisfactorily overcome, and on ount these figures do not represent the facts with reference arcasses, with quite the definiteness that was desired.

e percent of fat in these cross-sections is due very largely ubcutaneous deposit. The corn lots do not excel others in tter to the same extent as in the percent of fat laid down he muscles. In both series the linseed oil meal lots rank irst or second as to percent of fat, either on the basis of the neat, or on the basis of the water-free meat.

e relative percentages of protein and fat, show that this ceedingly fat meat, even though these hogs would have been nly about two-thirds fattened. The fat in the water-free ries between 75.82 percent in the "thin" shotes of the ot and nearly 90 percent in several others.

e percentage of water in the fat-free meat of the corn lots, nd 7, was as in the tenderloins, very high; in these cross-s it being decidedly higher than in other lots in both series, ce reinforcing our previous observations in regard to this specific influence of the corn. Some other lots were fatter, l others were not so fat, but in none of them was there so ater in the fat-free meat.

CONCLUSIONS FROM EXPERIMENT I.

In a comparison of corn alone, with corn supplemented b wheat middlings, linseed oil meal, soy beans, tankage and germ o meal for full-feeding growing and fattening hogs,—all rations ex cept the corn having the same nutritive ratio, namely 1:6.5,—as corn varied in cost between 40 and 60 cents per bushel, wheat middling varied in value between $20 and $27 per ton, linseed oil meal betwee $38 and $57 per ton; soy beans between $41 and $61 per ton; tankag between $68 and $102 per ton, and germ oil meal between $20 an $30 per ton. (Table VII, p. 252.)

To yield a profit these supplements would have to be bough at prices lower than these valuations. The relative profits in th use of these supplements depends not only on the above "replace ment values", but we must also consider the relative proportion o each in the balanced ration.

The six rations ranked as to palatability in the order in whicl the supplements are named:

1st.	Linseed oil meal.	4th.	Wheat middlings.
2nd.	Digester tankage.	5th.	Germ oil meal.
3rd.	Soy beans.	6th.	Corn alone.

Where hogs were full-fed on these rations, the middlings ratio was 23 percent more efficient than corn alone, the linseed oil mea ration 32 percent, the soy bean ration 38.5 percent, the tankag ration 32.6 percent, and the germ oil meal ration 17.6 percent mor efficient to cause gain in weight. (Table VI, page 250.)

Where these six rations were fed in practically equal but some what restricted amounts, the middlings ration was 28.9 percen more efficient than corn alone, the linseed oil meal ration 29.8 per cent, the soy bean ration 22.6 percent, the tankage ration 18.1 per cent, and the germ oil meal ration 16.4 percent more efficient tha corn by itself.

The soy bean, tankage, and linseed oil meal rations produce equal gain in weight from the same expenditure of digestible nu triment; the wheat middlings, germ oil meal, and straight corn rations were much less efficient.

Linseed oil meal, tankage, and soy beans were both very ef ficient and very palatable as supplements to corn; middlings wa efficient in the production of increased weight, but was much les palatable, while germ oil meal was neither efficient nor palatable as compared with the other supplements.

The character of the increase produced by these rations was te different. The tendency of five of these rations to cause wth of muscle and of internal organs was in the following order; eat middlings, linseed oil meal, soy beans, tankage and corn alone. is was practically in accord with the phosphorus content of the ions; the tankage ration, however, failed to make growth in ord with its phosphorus content, probably because of the fact t its phosphorus was present mostly as bone. (Tables XI, XII, l XIII, pages 261 and 262.)

The tendency of these rations to fatten, as evidenced by the rease in the leaf-lard, was in the reverse order from that indiing tendency to cause growth.

The probability is that corn does not contain as much phosorus as is necessary to the *maximum* muscular growth of which animal is capable.

Corn alone caused a deposition of much more fat within the scles, that is, between the fibers, than any other ration. (Table V, page 263.)

The tenderloin muscles of the corn-fed hogs contained less ter than muscles from any other lot, but the percentage of water the fat-free muscles of these corn-fed hogs was higher than in y other lot in the limited ration series, and exceeded only by the kage lot in the full-fed series. The tankage ration was 92 perit corn.

In the meat of the cross-sections of the carcasses, the fat-free at of the corn-fed hogs, in both series, contained decidedly more ter than did any other lot, though the percentage of water in the at as a whole was very low. (Table XV, page 265.)

The tenderloin muscles of the corn-fed hogs, in both series, re lower in protein than the muscles of any other lot. In the oss-sections the protein was also low.

The ash in the tenderloin muscles and cross-sections of the rn-fed hogs, in both series, was higher in the fat- and water-free at than it was in the meat from the middlings, soy beans, and rm oil meal lots; and in two cases out of the four, was higher an in the tankage lots.

When compared with these more highly nitrogenous rations, rn by itself seems to produce smaller muscles which are pecurly rich in fat; the moisture content of the meat as a whole is low, it the moisture in the fat-free meat is very high; the protein itself low in amount, but the proportion of ash to protein is rather high.

The most striking peculiarity of the linseed oil meal ration is e high proportion of ash to protein in the meat produced by this ed.

TABLE XVI: PERCENTAGE COMPOSITION OF FOODSTUFFS USED IN EXPERIMENTS II AND III.

	Water	Nitrogen-free extract	Protein	Ether extract	Crude fiber	Ash	Calcium	Magnesium	Potassium	Sodium	Sulphur	Phosphorus	Chlorine
Corn	16.68	67.76	8.67	4.10	1.65	1.36	.009	.110	.280	.046	.141	.295	.040
Hominy	15.97	75.01	7.61	.86	.23	.36	.004	.018	.096	.011	.121	.049	.048
Blood flour	11.44	......	82.50	1.00	......	3.04	.390	.068	.096	.370	.656	.210	.280
Bone meal	......	......	24.59	......	......	63.31	24.120	.530	.076	.548	.100	11.390	.041
Bran extract	92.58	4.95	1.40	......	......	1.20	.018	.148	.253	.026	.037	.261	.004

The germ oil meal ration occupied the opposite extreme from the linseed oil meal as regards the ash content of the tenderloin muscles, the percentage being lower than with any other lots.

In a number of lots there was less fat in the tenderloin muscles of the hogs which were fed for sixty days than there was in the muscles of the check lot, which was killed when the experiment began, and also in several lots there was an apparent loss of ash from the fat- and water-free meat during fattening. These facts are due to the hogs' being essentially corn-fed at the time the experiment began.

The increase in live-weight of the corn-fed hogs was more largely internal fat, and less largely muscles, than in any of the hogs which received higher-proteid ration. The hogs which received wheat middlings occupied the opposite extreme in this matter; their increased weight was more largely muscle, and less largely internal fat, than in any other lot. This comparison has an important bearing on the feeding of breeding animals, on whose reproductive efficiency excessive development of internal fat has an injurious effect, probably through restriction of circulation in the sexual organs, by the mechanical pressure of surrounding fat. (Table XI, page 261).

EXPERIMENTS II AND III

The general method of work was the same as in Experiment I. As in this series, five hogs were fed in each lot, one lot was killed at the beginning of each experiment, to serve as a basis for judgement as to changes produced by the experimental feeding, and a second lot was fed on corn alone, as a further basis for comparison.

The rations fed in these experiments were as follows:

EXPERIMENT II

Lot 1 Corn.
" 2 Hominy, blood-flour, bran-extract, (larger amount).
" 3 Hominy, blood-flour, lecithin.
" 4 Hominy, blood-flour, bran-extract, (smaller amount).
" 5 Hominy, blood-flour, bone-meal.
" 6 Hominy, blood-flour, sodium phosphate.
" 7 Check lot, killed at beginning of experiment.

EXPERIMENT III

Lot 1 Corn.
" 2 Check lot, killed at beginning of experiment.
" 3 Hominy, blood-flour, bran-extract.
" 4 Hominy, blood-flour, bone-meal.
" 5 Hominy, blood-flour.

TABLE XVII: DIGESTION COEFFICIENTS OF THE FOODSTUFFS USED IN EXPERIMENTS II AND III

	Protein Percent	Nitrogen-free extract Percent	Crude fiber Percent	Et ext Per
Corn	86	95	40	7
Hominy	86	95	40	7
Blood flour	62	....	..	10
Bran extract	76.2	86.2	..	..

TABLE XVIII: DIGESTIBLE NUTRIENTS PER HUNDREDWEIGHT OF FOODSTUFFS USED IN EXPERIMENTS II AND III

	Protein Pounds	Carbohydrates Pounds	E ext Po
Corn	7.456	65.032	3
Hominy	6.545	71.362	
Blood flour	51.150	......	1
Bran extract	1.067	4.267	.

The digestion coefficients are, as in Experiment I, lar assumed, but the same basal ration was fed in each case, and h if there is error in these coefficients it is the same in each lot, does not affect comparisons.

The hominy is assumed to have the same digestion coeffici as the whole corn.

The blood-flour has been assigned the same coefficient reported by Dietrich and König, (Composition and Digestibilit Cattle Foods, Vol. II).

The bran-extract is assigned the same coefficients as w middlings, as determined by Snyder of Minnesota.

In Experiments II and III we have considered the bal between the inorganic acids and bases in the rations fed. appears to be a matter of much importance, at least as fundam a one as the balance between proteids and non-proteid organic n ents, the so-called nutritive ratio. (Table XIX, pages 271 and 2

The significance of this factor of mineral base and acid bal is discussed by the author in Ohio Bul. 207. Very briefly the are as follows: There are constantly being formed in the an body, from the foods and from the tissues, inorganic acids w must be neutralized in order that the neutrality of the liquids

TABLE XIX: AVERAGE DAILY NUTRIENTS PER HEAD. EXPERIMENT II.

Lot	Rations		Digestible protein	Digestible starch equivalent*	Nutritive ratio	Calcium	Magnesium	Potassium	Sodium	Sulphur	Phosphorus	Chlorine	Excess normal acid
		Grams	Grams	Grams		Grams	Grams	Grams	Grams	Grams	Grams	Grams	C. C.
1	Corn	2114.2	157.6	1532.7	1 : 9.73	.199	2.326	5.920	.973	2.961	6.237	.846	217.90
2	Hominy Blood-flour Bran extract, (larger amt.)	1991.8 165.6 2039.4	236.7	1543.1	1 : 6.52	1.092	3.500	7.239	1.358	4.236	6.041	1.491	149.11
3	Hominy Blood-flour Lecithin	2068.9 187.3 4.00	231.2	1512.8	1 : 6.54	.822	.504	2.166	.921	3.728	1.562	1.518	198.50
4	Hominy Blood-flour Bran-extract, (smaller amt.)	2074.3 181.4 779.3	236.8	1550.4	1 : 6.55	.986	1.675	4.140	1.100	3.980	3.429	1.531	176.50
5	Hominy Blood-flour Bone-meal	1821.2 162.4 20.9	202.3	1331.8	1 : 6.58	5.747	.552	1.920	.915	3.286	3.610	1.337	54.91
6	Hominy Blood-flour Sodium phosphate	2068.4 187.3 1.8	231.2	1512.8	1 : 6.54	.822	.504	2.166	1.152	3.728	1.562	1.518	188.48

* Nitrogen-free extract and ether extract.

TABLE XIX: AVERAGE DAILY NUTRIENTS PER HEAD. EXPERIMENT III. Concluded.

Lot	Rations Grams		Digestible protein Grams	Digestible starch equivalent* Grams	Nutritive ratio	Calcium Grams	Magnesium Grams	Potassium Grams	Sodium Grams	Sulphur Grams	Phosphorus Grams	Chlorine Grams	Excess normal acid C. C.
1	Corn	1426.9	106.5	846.4	1 : 9.73	.134	1.571	3.998	.657	2.013	4.212	.571	147.14
3	Hominy Blood-flour Bran-extract	1548.6 171.9 589.7	195.6	1158.5	1 : 5.92	.842	1.272	3.144	.958	3.214	2.655	1.245	138.63
4	Hominy Blood-flour Bone-flour	1570.4 174.6 11.0	191.9	1149.4	1 : 5.98	3.406	.463	1.684	.879	3.054	2.390	1.247	90.86
5	Hominy Blood-flour	1286.9 143.3	157.9	945.1	1 : 5.98	.616	.332	1.378	.672	2.500	0.934	1.031	122.70

* Nitrogen-free extract and ether extract.

tissues may be maintained and the continuance of life thus rendered possible. The basic minerals in foods contribute to one side of this account, and the acid minerals to the other. An amount of acid mineral elements in the food in excess of the animal's capacity to neutralize them in normal ways may cause a withdrawal of basic minerals from the body, and, in consequence, most serious disturbances of nutrition.

The basic mineral elements considered in this connection are calcium, magnesium, potassium, and sodium; the acid minerals, sulphur, phosphorus, and chlorine.

In determining this balance between basic and acid minerals, we compute each to cubic centimeters of normal solution; that is, so that one cubic centimeter of any base will exactly neutralize one cubic centimeter of solution of any of the acid elements. Phosphoric acid is considered to be neutralized when two of its hydrogen atoms are replaced.

A peculiar relationship between the actions of calcium and magnesium in the body requires that a definite proportion between the quantities present in its liquids be maintained. They appear to be antagonistic, and an excess of magnesium occasions the liberation of calcium in quantity sufficient to counteract the effects of this excess of magnesium. The excess of both is then excreted. Thus an excess of magnesium, in proportion to calcium, may cause, just as may acid mineral elements, a withdrawal of calcium from the body, and pathological consequences such as usually result only from an excess of acids.

In Experiments II and III the rations are all characterized by an excess of mineral acid over mineral base.

The only differences of moment in this regard among the rations are in the somewhat lower excess of acid in the bone meal lot than in others, and the considerably greater excess of acid in corn than in the mixed rations. The corn ration besides having the most acid ash, has the least calcium, sodium, chlorine and sulphur, and the most magnesium, potassium and phosphorus, and the smallest proportion of proteid to non-proteid organic nutrients.

Experiment II. The hogs used in this experiment weighed about 125 pounds each; were mostly grade Poland Chinas of common quality; were six months old, in stock condition, and had been raised on corn and grass. The preliminary feeding occupied two weeks' time. The experiment was conducted during April and May of 1906.

In this test we sought to learn how a lack of phosphorus affects (1) the development of swine, and (2) the composition of their tissues; and (3) to compare bone meal, water extract of wheat bran, sodium

phosphate and lecithin as sources of phosphorus for growing pigs. In this experiment we consider the nutritive values of two organic phosphorus compounds, phytin, the principal phosphorus compound in the bran-extract, and lecithin; and two inorganic compounds, sodium phosphate, and calcium phosphate, as found in bone meal.

The distinction between organic and inorganic phosphorus compounds is largely arbitrary, and not always satisfactory, since inorganic salts of phosphoric acid, may enter into combination with organic compounds, and thus become organic phosphorus, without the agency of any vital process. Hence this distinction is not clean-cut and consistent. There is, however, a general dissimilarity between organic and inorganic phosphorus compounds, using the terms in the usual signification, and also a marked distinction in the nutritive values of these two groups. The usefulness of the distinction appears to outweigh its inaccuracies.

As a standard basal ration we adopted pearl hominy and blood-flour, which contained 82.5 percent of protein and only two-tenths of one percent of phosphorus. The hominy consists of the corn kernel minus the bran, or skin, and the germ, and is very much lower than corn in fat, fiber and ash constituents. These feeds furnished us a cheap and palatable balanced ration which was very low in phosphorus, and constituted a satisfactory basal ration for our comparisons. In subsequent work we have used blood albumen and wheat gluten as proteid supplements. They contain still less phosphorus than does blood flour.

In this experiment Lot 1 received corn alone; Lots 2 and 4 received different amounts of water-extract of wheat bran with their basal ration of hominy and blood-flour. This extract was prepared by soaking bran in luke-warm water, from one feeding period until the next, the hogs being fed twice daily. Two quarts of water were used in soaking each pound of bran. At feeding time the mash was put into a sack of thick cloth, and a cider press was found to be a quick and easy means of expressing the liquid. The feed, which in all lots was fed finely ground, was made into a moderately thick slop, either with the bran extract or with water. The extract was analyzed, and a correction was made in the basal ration for the two lots receiving it, so that the nutritive ratio might be the same in all cases, except with the corn lot. This bran extract was exceedingly rich in magnesium, potassium and phosphorus. The phosphorus was present mostly as phytin, a salt formed by the union of calcium, magnesium and potassium with phytic acid, a complex, organic, phosphoric acid which constitutes a large proportion of the phosphorus compounds of seeds. Where bacterial fermentation was considerable

during the preparation of the extract, the magnesium and phosphorus contents were more than twice as great as when sterile utensils and water were used, but in both cases the relation of total mineral bases to mineral acids was practically the same. The extract was in this regard about neutral.

Lot 3 consisted of but a single hog, the cost of lecithin making it impracticable to feed more. Four grams per day were fed to this hog, the lecithin being provided by Dr. W. Koch, of the Department of Physiology. The material was emulsified in water and added to the hominy and blood-flour. When it is considered that this lecithin contained but 3.883 percent of phosphorus it is apparent that the total amount fed did not provide any considerable quantity of this element. It was used with the hope of learning of its function in nutrition. It is a universal cell constituent of plants and animals, but does not constitute a large proportion of the total phosphorus of foods..

Lot 6 received with its basal ration just enough di-sodium phosphate to furnish to each pig the same amount of phosphorus as was received in lecithin by the pig in Lot 3. We refer to Lot 6 as the "low-phosphorus" lot.

In Lot 5, raw bone-meal was fed mixed with the ration. The bone-meal contained nitrogen equivalent to 24.59 percent of protein, but as this was doubtless present mostly as collagen, a substance of low food value, and the total amount of bone fed was only 13 pounds, no account of this protein was taken in the compounding of the rations. The phosphorus of this foodstuff was present mostly as tri-calcium phosphate.

Salt was given apart from the feed in each lot.

This experiment lasted 56 days.

It was hoped that all of the lots might be kept together in the amount of feed consumed but the rations were peculiar and it was soon apparent that each one would have to be fed with reference alone to the pigs consuming it.

With Lot 2 we attempted to find the amount of bran-extract that could be fed. It seems to be easy to overfeed with it, the pigs being willing to take much more of it than is beneficial to them. These pigs would cease eating before having cleaned up the feed well; appeared uneasy, coughed, gritted the teeth and allowed much saliva to drip from the mouth. Their joints became sore and swollen, and they moved around with reluctance and difficulty. These symptoms and other evidences of discomfort largely disappeared after the amount of bran-extract was cut down.

Lot 4, receiving less bran-extract, ate heartily and consis at all times, and we must base our conclusions as to the effe bran-extract as a food on the record of this lot. The amount of extract fed to this lot was regarded as very satisfactory. average amount fed was one pound to 2.89 pounds of dry Probably a much greater amount could have been fed had we chalk with the bran-extract to protect the pigs from the effe the excessive amount of magnesium present.

The bone-meal lot was hard to feed. These hogs frequ went off feed, apparently because of the bone-meal, and o account the total amount of feed eaten was smaller than in any lot. We succeeded much better in feeding this bone-meal grinding it to a fine flour in a pebble mill. This, however, had learned by experience.

The lecithin pig, Lot 3, was always ravenous for his feed ar ration was clearly more palatable than any other used in experiment.

The other low-phosphorus lot, No. 6, also ate well. Thes lots, Nos. 3 and 6, and No. 4, which received the smaller amou bran-extract, were never fed up to their full capacity.

Lot 1, which received corn alone, ate consistently throu the experiment; doing very well indeed for pigs so fed. record was unusually creditable to corn alone as a hog feed. is, of course, largely due to the shortness of the experiment. were fed as much as they would eat but did not consume as feed as the other lots which were not fed to the limit of appetites.

These rations affected the digestive system very differ The corn ration was much the most laxative in its action. ration of hominy and blood-flour was very constipating, most Lots 3 and 6, receiving lecithin and sodium phosphate, respect and least so in Lots 2 and 4, receiving bran-extract. The bone lot was usually constipated, but sometimes scoured. This lot rough coats, and did not shed off well. They did not like bone-me mixed with the feed. The constipating character of the basal r is doubtless due to its low contents of fibrous material and mi matter.

Experiment III, conducted during October, November December, 1906, was a repetition of Experiment II, except tha lecithin lot, and the lot receiving the larger amount of bran-ex were omitted, and no sodium phosphate was fed to the low-phorus lot.

The facts that the bone-meal lot in Experiment II was n entirely normal state of nutrition, and did not make as large in weight as those lots with which we wished to compare it, ren

close comparisons of results a little doubtful. Hence it seemed desirable to repeat this work. In Experiment III, as will be seen by Table XIX, page 272, the bone-flour lot, No. 4, ate more feed than the low-phosphorus lot, No. 5, and practically as much as the bran-extract lot. This gives us a better basis for judgment as to the capacities of the bone-meal ration.

The pigs on which Experiment III was conducted were much superior to those used in the previous experiments. They were four-months-old, pure-bred Duroc Jerseys; they were all sired by the same boar; their dams were all by the same boar, and their grand-dams were closely related; further than this, they had been raised from birth together. These were growing pigs rather than growing and fattening hogs, as in the previous experiments.

The method followed was the same as in the previous experiment, except that the bran-extract was fed in the proportion of 150 cubic centimeters of the extract to each pound of dry feed given. This is the equivalent of a quart of the extract to 6.31 pounds of feed. This lot of pigs was in the best of health throughout the experiment.

The bone-meal was reduced to a fine flour, and fed in this condition from the beginning. We did not experience difficulty in the feeding of the bone in this shape.

The corn ration was not so well relished by these pigs as by the older ones in Experiment II, (Table XIX, page 271), and though these pigs were three months younger and of decidedly better quality, the gains were much more expensive. The younger the pig the less nearly a perfect feed is corn by itself.

With these young pigs there is also a much greater difference between the bran-extract and the low-phosphorus lots in favor of the former; that is, the lack of the ash constituents in the hominy and blood-flour ration was much more keenly felt by the young pigs in this experiment than by the older and larger ones of Experiment II, the younger ones having a less extensive reserve supply of the ash constituents on which to draw to make good the deficiencies of the ration.

As in the previous experiment the bran-extract proved to be slightly laxative, and the hominy and blood-flour without the addition of this supplement, very constipating.

The bran-extract lot ate their food with the keenest relish, though not particularly more so than the bone-flour lot. The low-phosphorus lot did not eat very heartily, and their rough, dead-looking coats gave them an unthrifty look. The corn lot had the poorest appetites of all, and looked the most poorly nourished.

The largest pig in the corn lot was taken out of the experimen[t] being rendered unfit by an accidental injury. This leaves avera[ge] weights light in this lot.

TABLE XX: FEEDS AND GAINS IN WEIGHT.

EXPERIMENT II.

Lots	Rations	Digestible nutriment per 100 lbs. gain Lbs.	Ave. initial weight Lbs.	Ave. final weight Lbs.	Numb[er] of pig[s] in lot
1	Corn	364.9	125	182.2	5
2	Hominy; blood-flour; bran-extract, (larger amount)	298.6	126.8	200.4	5
3	Hominy; blood-flour; lecithin	231.5	127	220	1
4	Hominy; blood-flour; bran-extract, (smaller amount)	271.7	124	205.2	5
5	Hominy; blood-flour; bone-meal	295.0	126.6	190.8	5
6	Hominy; blood-flour; sodium phosphate	272.5	124.8	203.8	5
7	Check lot; killed		125.2		5
	EXPERIMENT III				
1	Corn meal	554.2	67	94.25	4
2	Check lot; killed	....	78.6	.....	5
3	Hominy; blood-flour bran-extract	330.5	78.4	132.6	5
4	Hominy; blood-flour bone-flour	365.0	79.6	128.2	5
5	Hominy; blood-flour	447.5	78.4	111.0	5

Length of Experiment II, 56 days; of Experiment III, 60 days.

Experiment II. Lot 2, where the bran-extract was fed in the excessive amount, did not make as economical gains in weight as Lot 6, the low-phosphorus lot. Lot 5, the bone-meal lot, also failed to make as economical gains as the low-phosphorus lot. The excess of magnesium in ration No. 2, and the depressing effect of the bone-meal on the digestibility of protein in ration No. 5 are at least in part responsible for the poor showing made by these rations; for Lot 4, with the lower amount of bran-extract, used it to advantage, and made as efficient gains in weight as did Lot 6, the low-phosphorus lot; that it did not make more economical gains in weight, appears to be due to the shortness of the experiment. As is well known, an animal may for considerable periods of time give off more phosphorus in the urine and feces than is present in the food. The effects of phosphorus starvation are not immediately manifest. There are reserves of phosphorus in the body which may be used to supplement a ration which is lacking in this element. This table however, gives no hint as to the character of the increase. It is here that we must hope to find more significant results.

It is apparent, nevertheless, that these various balanced rations, however artificial their character, were all decidedly more efficient than corn alone. The low-phosphorus lot withstood a temporary lack of ash constituents to much better advantage than the corn lot withstood the lack of protein.

Regarding Lot 3, the lecithin pig, we publish these results because we do not wish to suppress any of the evidence, whatever its trend, but the results from a single individual are not fairly comparable with an average of results from five. This evidence is not entirely without weight, however, and so far as it goes is favorable to the belief that lecithin is a valuable nutrient.

Experiment III. The amounts of digestible nutriment eaten per hundred pounds of gain in weight were consistent with the character of the rations. The bran-extract lot received most nearly a normal ration. This lot made the most efficient gains. The bone-flour lot ranked next, it being apparent that, in the amounts fed, this supplement was less efficient than bran-extract to furnish what was lacking in the hominy and blood-flour ration.

The hominy and blood-flour ration, containing an abundance of easily digestible protein and starch, and being in a palatable form, was still decidedly lacking in some constituents necessary to the nourishment of growing pigs.

The ration of corn alone contained less protein, but more c the ash constituents, and was still less efficient than the ration c hominy and blood-flour. In both Experiments II and III the cor ration was the highest in phosphorus and lowest in calcium and i protein.

Experiment II, (Table XXI page 281). The killing of these hog was conducted at a local slaughter house. The cross-section, instea of being taken at the sixth rib, as in Experiment I, consisted of three-rib cut taken just behind the shoulder. The thickness of th back-fat was measured on the rear aspect of this section. Sample of the liver and kidney as well as the tenderloin were prepared fo analysis, but the chemical study of the cross-section was discontin ued, our judgment as to the fatness of the animals being based on th relation of dressed to live-weight, the weight of the leaf-lard, th thickness of the back-fat, and the analyses of the tenderloins.

At the time of killing, the hogs in the six lots fed would hav graded as to condition in the market, as follows:

Lot 1. 1 choice, 1 good, 3 medium, (corn alone).
" 2. 3 choice, 1 good, 1 medium, (larger amount of bran-extract).
" 3. 1 good, (lecithin).
" 4. 4 choice, 1 medium, (smaller amount of bran-extract).
" 5. 1 choice, 1 good, 2 medium, 1 common, (bone-meal).
" 6. 2 choice, 2 good, 1 medium, (low phosphorus ration).

Three lots of these hogs increased the thickness of the back-fa from one inch to more than two inches in fifty-six days, but non of them doubled the weight of the tenderloin muscles. The leaf lard and the kidneys also increased rapidly in weight, much mor so than the lungs, spleen, heart and liver.

Experiment III. At the time these shotes were killed, th pigs in the four lots averaged in weight between 94.25 and 132. pounds; the pigs in the check lot, killed when the experiment began weighing 78.6 pounds each.

Judging these pigs by the fat-hog standard of the market the would have graded as follows: The corn lot, and the hominy an blood-flour lot, "common"; the bran-extract lot, 1 "choice" 3 "good", 1 "common"; and the bone-flour lot, "good". This las was clearly the fattest lot.

The bran-extract lot, having gained the most in weight, excelle all the other lots in the development of each of the parts observe except that the bone-flour lot excelled it in thickness of back-fa and in weight of leaf-lard, the apparent fatness of these hogs whe alive being borne out by the examination of the carcasses.

TABLE XXI: SLAUGHTER RECORDS. AVERAGE WEIGHT OF PARTS.

EXPERIMENT II.

Lots	Rations	Gross dressed weight	Heart	Liver	Spleen	Lungs	Leaf-lard	Kidneys	Tender-loins	Thickness of back-fat
		Pounds	Ounces	Pounds	Ounces	Pounds	Pounds	Ounces	Grams	Inches
1	Corn	137.33	8.30	2.73	3.20	1.80	5.88	6.03	262.2	1.89
2	Hominy; blood-flour; bran-extract, (larger amount)	158.87	9.15	3.57	3.93	1.84	5.47	10.53	336.8	2.10
3	Hominy; blood-flour; lecithin	165.69	10.63	3.66	4.00	1.43	7.19	8.00	374.0	1.75
4	Hominy; blood-flour; bran-extract, (smaller amount)	159.81	9.4	3.08	3.13	2.03	6.61	8.75	357.4	2.08
5	Hominy; blood-flour; bone-meal	146.49	8.53	3.26	3.16	1.39	5.49	9.18	302.8	1.83
6	Hominy; blood-flour; sodium phosphate	160.72	8.88	3.40	3.33	1.81	6.22	8.95	330.6	2.16
7	Check lot	92.30	6.46	2.49	2.34	1.33	3.71	4.40	201.6	1.02
	EXPERIMENT III.									
1	Corn	66.9	4.49	1.77	1.25	1.55	3.58	3.83	121.1	1.46
2	Check lot	51.45	4.50	1.83	1.43	.88	1.16	4.25	134.1	1.05
3	Hominy; blood-flour; bran-extract	96.4	6.75	2.72	2.06	1.60	4.21	7.75	208.9	1.52
4	Hominy; blood-flour; bone-flour	92.7	6.17	2.54	1.62	1.51	4.59	6.05	188.7	1.59
5	Hominy; blood-flour	79.1	5.90	2.06	2.04	1.53	3.29	6.05	174.0	1.50

TABLE XXII: RELATION OF PARTS TO DRESSED CARCASS

EXPERIMENT II

Lots	Rations	Percent gross dressed to live weight	Per-cent of heart	Per-cent of liver	Per-cent of spleen	Per-cent of lungs	Per-cent of leaf-lard	Per-cent of kid-neys	Per-cent of tende[rloins]
1	Corn	75.37	.378	1.988	.146	1.311	4.28	.275	.421
2	Hominy; blood-flour; bran-extract, (larger amount)	79.28	.360	2.247	.155	1.158	2.44	.414	.467
3	Hominy; blood-flour; lecithin	75.31	.401	2.209	.151	.863	4.34	.302	.498
4	Check lot	77.88	.368	1.927	.122	1.270	4.14	.342	.493
5	Hominy; blood-flour; sodium phosphate	76.78	.364	2.225	.135	.949	3.75	.392	.455
6	Hominy; blood-flour; bone-flour	78.86	.345	2.115	.129	1.126	3.87	.348	.453
7	Hominy; blood-flour; bran-extract, (smaller amount)	73.84	.437	2.698	.158	1.441	4.02	.298	.482
	EXPERIMENT III								
1	Corn	71.0	.420	2.64	.012	2.32	5.35	.359	.399
2	Check lot	66.5	.547	3.55	.017	1.71	2.25	.516	.575
3	Hominy; blood-flour; bran-extract	72.7	.438	2.82	.013	1.66	4.37	.502	.478
4	Hominy; blood-flour; bone-flour	72.3	.416	2.74	.011	1.63	4.95	.410	.449
5	Hominy; blood-flour	71.3	.466	2.60	.016	9.31	4.16	.480	.485

Lot 1, in Experiment III, fed on corn alone, contained but four pigs, one of the original five, t[he] largest, having been removed early in the experiment because of a mechanical injury; the other lo[ts] contained five pigs each.

Experiment II. The low-phosphorus lot, No. 6, (see above table) dressed a high percentage of carcass to live-weight and, as will b[e] seen in Table XXI, page 281, had the thickest back-fat.

The corn lot dressed a low percentage of carcass to live-weight on account of the small amount of increase put onto the carcass though as a rule corn produces a carcass which, because of smal[l] viscera and thick fat, dresses out a high percentage of carcass t[o] live-weight. This lot was low in percentage of tenderloin and high in percent of leaf-lard.

The lungs of the corn lot were heavier in proportion to th[e] carcass, and the kidneys were lighter, than in any other lot.

It will be noted that the check lot had a larger percentage of heart, liver, spleen, and lungs than any of the lots that were fed, but the kidneys of the lots which received the balanced rations were heavier in comparison with the weight of the carcass than in the check lot; this doubtless being due to the protein in these rations, for the corn lot and this one only, did not increase its percentage of kidneys during the course of the experiment.

Experiment III. These lots of hogs each dressed about the same percentage of carcass to live-weight. The bran-extract lot exceeded the bone-flour lot, even though not so fat. It would seem that the excess of muscle in the bran-extract lot more than offset the excess of fat in the bone-flour lot. The corn lot, and the hominy and blood-flour lot, which received the low-protein and the low-phosphorus rations respectively dressed the lowest percentages of carcass to live-weight, since neither of these rations was well adapted to the production of growth.

The carcasses of the corn-fed hogs contained the largest percent of leaf-lard and lungs and the smallest percent of kidneys and tenderloin muscles.

Experiment II, (Table XXIII, page 284). The percent of gain in the live-weight was about the same in Lots 4 and 6, the bran-extract and the low-phosphorus lots. Both of these gained decidedly more rapidly than did the corn lot, No. 1. Even the difficulty which we had with the feeding of bone-meal to Lot 5 did not prevent this lot from exceeding the corn lot in increased weight. The hearts, livers, kidneys and tenderloin muscles of these corn-fed pigs gained very poorly. This lot gained fairly well, however, in thickness of back-fat and in weight of leaf-lard.

It is worthy of note that the bone-meal lot, No. 5, while gaining 51 percent in live-weight, gained 105 percent in the ash of the bones and 48.5 percent in the weight of the muscles. This lot and the corn lot were the only ones which did not gain in muscle as fast as in live-weight.

Experiment III. The corn lot seems to have gained the least in live-weight, liver, spleen, kidneys and tenderloin muscles, but the loss of one pig renders the figures with reference to this lot of slightly uncertain value.

The bran-extract lot excelled the bone-flour and the low-phosphorus lots in percentage of gain in live-weight, heart, liver, spleen, lungs, kidneys and tenderloin mucles.

The bone-flour lot, however, excelled in the percentage of increase in leaf-lard, thickness of back-fat, and in the ash of the bones. This lot ate practically as much feed as the bran-extract lot, but probably because of the unavailability of bone phosphates for muscular growth, the digested nutriment was laid down as fat rather than as proteid increase.

The hominy and blood-flour, or low-phosphorus lot, was at a conspicuous disadvantage, as compared with the bran-extract and the bone-flour lots, in the formation of bone, the ration providing very little indeed that the pigs seem to have been able to use for this purpose. The ability of this lot to lay on fat and muscle was not hindered to nearly so great an extent as was its ability to grow bone.

TABLE XXIII: PERCENT OF INCREASE IN WEIGHTS AND MEASUREMENTS OF PARTS.

Lots	Rations	Live weight	Heart	Liver	Spleen	Lungs	Leaf-lard	Kidneys	Tender-loins	Thickness of back-fat	Ash of humerus
	EXPERIMENT II										
1	Corn	45.76	28.68	8.64	36.7	35.3	58.9	37.4	30.25	85.3	44.7
2	Hominy; blood-flour; bran-extract, (larger amount	58.04	39.9	41.7	65.8	36.3	45.5	136.1	64.93	104.0	44.3
3	Hominy; blood-flour; lecithin	73.23	62.3	44.7	68.8	6.0	91.0	79.4	82.89	70.0	68.6
4	Hominy; blood-flour; bran-extract, (smaller amount	65.48	46.9	24.7	34.9	53.8	80.1	100.7	78.97	106.0	61.2
5	Hominy; blood-flour; bone-meal	50.71	30.6	29.4	33.3	3.0	46.3	106.3	48.50	77.7	104.9
6	Hominy; blood-flour; sodium phosphate	63.30	37.9	37.1	42.9	36.1	68.1	103.9	64.48	111.8	56.6
	EXPERIMENT III										
1	Corn*	40.7	19.7	12.5	-9.1	108.9	224.3	-2.3	7.36		41.6
3	Hominy; blood-flour; bran-extract	69.1	50.0	49.0	44.6	81.8	262.9	82.4	55.8	44.3	40.5
4	Hominy; blood-flour; bone-flour	61.0	35.3	37.4	12.3	69.7	292.3	40.8	37.0	50.0	43.6
5	Hominy; blood-flour	41.6	31.1	12.9	43.2	73.9	183.6	42.4	29.8	43.2	3.2

* Computed with reference to four of the pigs of the check lot.

TABLE XXIV: INCREASE IN WEIGHT OF VARIOUS PARTS AND ORGANS IN RELATION TO GAIN IN LIVE-WEIGHT.

EXPERIMENT II.

Lots	Rations	Heart	Liver	Spleen	Lungs	Leaf-lard	Kidneys	Tender-loin	Thickness of back-fat	Ash of humerus
1	Corn....	.627	.211	.802	.771	1.287	.817	.661	1.864	.977
2	Hominy; blood-flour; bran-extract, (larger amount).....................	.687	.718	1.134	.625	.784	2.345	1.119	1.792	.763
3	Hominy; blood-flour; lecithin	.861	.610	.939	.082	1.243	1.084	1.132	.956	.937
4	Hominy; blood-flour; bran-extract, (smaller amount)...................	.716	.377	.533	.822	1.223	1.538	1.206	1.619	.935
5	Hominy; blood-flour; bone-meal.......	.603	.580	.657	.059	.913	2.096	.956	1.532	2.069
6	Hominy; blood-flour; sodium phosphate.........	.599	.586	.678	.570	1.076	1.641	1.019	1.766	.894

EXPERIMENT III.

Lots	Rations	Heart	Liver	Spleen	Lungs	Leaf-lard	Kidneys	Tender-loin	Thickness of back-fat	Ash of humerus
1	Corn..................................	.484	.307	—.224	2.675	5.511	—.057	.181	1.516	1.022
3	Hominy; blood-flour; bran-extract....	.724	.709	.645	1.184	3.805	1.192	.808	.641	.586
4	Hominy; blood-flour; bone-flour........	.580	.613	.202	1.143	4.792	.667	.607	.820	.715
5	Hominy; blood-flour..................	.748	.310	1.039	1.776	4.413	1.019	.716	1.039	.077

Experiment II. The most significant data of the experi are set forth in the preceding table. The large increase i weight of the leaf-lard and in the thickness of the back-fat ind a large percentage of fat in the increase of live-weight, the cor naturally leading in these regards, and being last in gain of mu This lot also gained very little in weight of liver and kidney relation to gain in live-weight.

The increase in the low-phosphorus lot, No. 6, greatly exc the corn lot in percent of liver, kidneys and tenderloin mus The lack of protein and calcium in the corn seems to have more severely felt than the lack of phosphorus and potassiu the low-phosphorus ration.

The increase in the bran-extract lot, No. 4, was highe percent of heart, lungs, leaf-lard and tenderloin muscles than ir low-phosphorus lot. The rations being otherwise the same, it be concluded that the bran-extract furnished valuable nutr which were lacking in the low-phosphorus ration, these prob being phosphorus and potassium.

In the bone-meal lot the gain in weight was less largely m than in the low-phosphorus lot, while at the same time the portion of bone-ash in the increased weight seems to have three times as great. The addition of bone-meal to the r appears not to have added to its tendency to produce muscle.

The bran-extract, however, did cause an improvement in hominy and blood-flour ration, as regards both bone and m formation. Bran-extract seems to have a capacity that bone- does not to take part in proteid increase.

Experiment III. The bone-flour lot produced a sm proportion of muscle in the increase in weight than the low-p phorus lot, the rations differing only with regard to the pres of the bone-flour. Obviously the composition of the increase is rendered more largely muscle because of the addition of bone- to the hominy and blood-flour ration. The bran-extract ra however, produced a decidedly greater proportion of muscle in increase than did any other lot. We incline to ascribe difference in the usefulness of these supplements most largel the differences in the compounds of phosphorus contained in t

The corn ration, with its deficiency of protein, produc much smaller proportion of muscle in the increase than did other ration.

The proportion ot bone-ash in the increase was greater with the corn lot than with the bone-flour lot. The corn lot received more phosphorus than any of the other lots in this experiment. The low-phosphorus ration made peculiarly little increase in the ash of the bone, and the addition of bran-extract to this ration was of decided benefit in the deposit of ash in the bones.

The two lots which produced the greatest proportion of back-fat in the increase are the corn, and the low-phosphorus lots, these being the most abnormal rations, and those in which a lack either of protein, or of ash constituents, was disadvantageous to the construction of bone and muscle.

The slightly smaller proportion of muscle in the increase in the bone-flour lots, than in the low-phosphorus lots, in both these experiments, gives evidence of the depressing effect which calcium phosphate has on the digestibility of protein.

Experiment II, (Table XXV, page 288). The bones of the bone-meal lot, No. 5, were larger than in other lots, as is evidenced by their volume; the amount of ash was also greater; the ash per cubic centimeter of volume was greater, and the breaking strength greater than in other lots. Clearly bone-meal in the ration contributes to the nourishment of the bones, even though it appears not to be useful in muscle building.

The lack of protein in corn tends to reduce the size, density and strength of the bones, as is seen by comparing Lots 1 and 6, the latter containing more protein, but less ash, than the former.

Experiment III. The volume of the bones in the different lots differed but little. The smallness of the bones of the corn lot was partially due to the fact that the largest pig had been removed from this lot.

The bone-flour ration did not produce as large bones as the bran-extract ration, though the ash per cubic centimeter of volume was much greater; that is, the bone was denser. The bone produced by the low-phosphorus ration was less dense than any other.

The density of the bone of the corn, and the bone-flour lots was about alike.

The breaking strength was least with the low-phosphorus lot while the bran-extract, and bone-flour lots both ranked higher than the corn lot. It should be borne in mind that the bone-flour lot in this experiment received much less phosphorus than did the corn lot, but its greater amount of calcium appears to have been of benefit in the production of strong bone.

TABLE XXV: DATA CONCERNING DEVELOPMENT OF BONES

EXPERIMENT II.

Lots	Rations	Volume of each humerus	Ash in each humerus	Ash per c. c.	Breaking strength	Length	Longer transverse diameter	Shorter transverse diameter
		C. C.	Grams	Grams	Lbs.	Cm.	Cm.	Cm.
1	Corn	108.0	32.92	.3048	509	13.88	2.25	1.63
2	Hominy; blood-flour; bran-extract, (larger amount)	111.8	33.33	.2981	575	13.68	2.23	1.67
3	Hominy; blood-flour; lecithin	118.0	38.97	.3303	736	13.70	2.20	1.66
4	Hominy; blood-flour; bran-extract, (smaller amount)	117.6	36.39	.3094	676	13.74	2.34	1.68
5	Hominy; blood-flour; bone-meal	121.3	46.22	.3811	791	14.00	2.28	1.71
6	Hominy; blood-flour; sodium phosphate	112.5	35.59	.3164	624	13.90	2.33	1.69
7	Check lot	78.9*	22.80*	.2890*				

EXPERIMENT III.

Lots	Rations	Volume of each humerus	Ash in each humerus	Ash per c. c.	Breaking strength	Length	Longer transverse diameter	Shorter transverse diameter
1	Corn;	74.6	23.82	.319	502	13.1	1.83	1.37
2	Check lot	65.9	19.93	.3024	440	11.64	1.75	1.30
3	Hominy; blood-flour; bran-extract	100.1	28.01	.280	641	14.46	1.98	1.51
4	Hominy; blood-flour; bone-flour	94.4	28.97	.307	606	13.46	2.08	1.46
5	Hominy; blood-flour	93.7	20.56	.219	426	13.56	1.95	1.41

*Computed as a basis for reckoning increase made in other lots.

TABLE XXVI: ANALYSES OF TENDERLOIN MUSCLES

EXPERIMENT II

Lot	Rations	Water	Protein	Fat	Ash	Phosphorus	Water in fat-free meat	Fat in water-free meat	Proportion of phosphorus to protein	Proportion of ash to protein	Phosphorus in ash
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
1	Corn	73.51	19.73	5.17	1.09	.264	77.52	19.52	1.34	5.52	24.22
2	Hominy; blood-flour; bran-extract, (larger amount)	73.62	18.85	5.17	1.13	.196	77.63	19.60	1.04	6.00	17.35
3	Hominy; blood-flour; lecithin	74.63	15.78	4.27	1.10	.352	77.97	16.83	2.23	6.98	32.00
4	Hominy; blood-flour; bran-extract, (smaller amount)	72.74	20.67	4.22	1.21	.252	75.10	15.48	1.22	5.85	20.83
5	Hominy; blood-flour; bone-meal	72.83	20.13	5.12	1.08	.233	76.77	18.85	1.16	5.37	21.57
6	Hominy; blood-flour; sodium phosphate	72.87	20.74	5.14	1.10	.264	76.82	18.95	1.27	5.30	24.00
7	Check lot	73.57	18.53	4.97	1.10	.247	77.42	18.80	1.33	5.93	22.45

EXPERIMENT III

Lot	Rations	Water	Protein	Fat	Ash	Phosphorus	Water in fat-free meat	Fat in water-free meat	Proportion of phosphorus to protein	Proportion of ash to protein	Phosphorus in ash
1	Corn	73.39	17.68	6.16	1.07	.228	78.21	23.15	1.29	6.05	21.31
2	Check lot	76.35	19.42	3.04	1.13	.238	78.74	12.85	1.23	5.30	21.06
3	Hominy; blood-flour; bran-extract	73.74	21.85	3.90	1.03	.195	76.73	14.85	.81	4.71	18.93
4	Hominy; blood-flour; bone-flour	73.20	18.30	4.46	1.12	.222	76.62	16.64	1.21	6.12	19.82
5	Hominy; blood-flour	72.81	20.39	4.52	1.15	.228	76.26	16.62	1.12	5.64	19.83

The analyses of the muscles, livers and kidneys involved mu work which does not yield results of immediate practical valu These data, however, will assist us in learning how these tissues a organs vary in composition, and in some cases probable causes a interesting associations of factors are observed. After a sufficie accumulation of evidence we shall be able to say just how foo vary the composition of animals, and to interpret and apply t results in a practical way; but we must establish the facts befo attempting to draw conclusions.

The tenderloin muscles produced by Lot 1, the corn lot, Experiment II, (Table XXVI, page 289), were characterized as Experiments I and III by their high fat and low protein conter and by the high water-content of the fat-free meat.

In Experiment II there is more phosphorus in the muscles the corn-fed lot, in the meat as a whole, and in the protein, than in tl check lot, No. 7, which was not fed.

In Experiment III, however, the condition is reversed; in tl corn lot, No. 1, there being less phosphorus in the meat as a whol and in the protein, than in the check lot, No. 2. This is partial due to the greater age of the pigs in Experiment II. They thro to much better advantage on corn alone than did the younger pi in Experiment III. Further, the check lot in Experiment III ha been raised on foods containing more phosphorus than those which the check lot in Experiment II had been raised.

The low-proteid, high-phosphorus character of the corn ratio as compared with these others, shows itself in the composition of tl muscles.

In both Experiments II and III the percent of phosphorus the meat as a whole is the same in the corn lot and the low-pho phorus lot, but the proportion of phosphorus to protein is greate and the percent of phosphorus in the ash is greater in the corn lo in both experiments, than in the low-phosphorus lots, because of tl smaller amount of protein and of ash in the muscles of the corn-fe pigs. These differences are less in Experiment II, where the sodiu phosphate was fed to the low-phosphorus lot, than in Experiment I where the hominy and blood-flour were fed alone. In both e periments the gain in muscle was much greater on the low-pho phorus ration, which was high in protein, than on the corn ratio which was much higher in phosphorus, but lower in protein.

In both Experiments II and III there is quite decidedly les phosphorus in the meat as a whole, in the protein, and in the as in the muscles of the bran-extract lots than in the corn lots, in fa these bran-extract lots are lower in the phosphorus in the muscl

than any other, without exception, in either experiment, while at the same time these rations caused the greatest increase in the weight of these muscles. (Table XXIII, page 284).

The bone-meal and the low-phosphorus lots in these two experiments furnish a most interesting comparison.

Adding bone-meal to the ration of hominy and blood-flour increased the proportion of ash to protein in the muscles produced; did not increase the percentage of phosphorus, either in the muscle or in the ash of the muscle; and decreased the percentage of protein in the muscles.

In both experiments the undetermined constituents were slightly greater in amount with the bone-meal lot than with the low-phosphorus lot, which, assuming the work to be correct, might indicate a higher percentage of glycogen.

Bran-extract has a tendency to produce muscles containing a low percentage of phosphorus in the ash. In Experiment II, the bran-extract lots were lower than others in this regard, the lot receiving the most bran-extract being the lowest, and in Experiment III the bran-extract lot was again lowest of all. In both experiments the lot having the least phosphorus in the meat had received bran-extract. The rations, however, containing bran-extract were high in phosphorus.

The results from the analysis of the meat samples from the one pig which received lecithin with the basal ration of hominy and blood-flour, and which constituted Lot 3, in Experiment II, are regarded as having greater value than the weights of organs of this pig, and data regarding gains in weight. It would seem from these figures that the lecithin had tended to the production of muscles containing a high moisture content, low percentage of protein and of fat, very high percent of phosphorus, high percent of water in the fat-free meat, high percent of ash, and high proportion of phosphorus to protein, and high percent of phosphorus in the ash.

In the kidneys the lecithin lot contained a low percent of water, and was high in protein and in phosphorus, but the proportion of phosphorus to protein was not unusual. (Table XXVII, page 292).

The liver of this pig analyzed high in phosphorus, and high in the percent of phosphorus in the ash. (Table XXVIII, page 294).

Hence we may say regarding the lecithin lot, that the phosphorus content of the meat as a whole, in the muscles, was much higher than in any other lot; in the liver it was as high as in any lot, and in the kidneys it was exceeded only by the check lot which was not fed. The small amount of lecithin fed has produced these marked effects only because the basal ration to which it was added was exceedingly low in phosphorus compounds.

TABLE XXVII: ANALYSES OF KIDNEYS.
EXPERIMENT II.

Lots	Rations	Water	Protein	Fat	Ash	Phosphorus	Water in fat-free meat	Fat in water-free meat	Proportion of phosphorus to protein	Proportion of ash to protein	Phosphorus in ash
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
1	Corn	78.21	15.78	3.07	1.17	.232	80.69	14.09	1.47	7.41	19.83
2	Hominy; blood-flour; bran-extract, (larger amount	80.68	14.34	2.65	1.02	.243	82.88	13.72	1.69	7.11	23.82
3	Hominy; blood-flour; lecithin	78.80	16.38	2.89	1.15	.258	81.15	13.63	1.58	7.02	22.43
4	Hominy; blood-flour; bran-extract, (smaller amount)	79.99	15.62	2.57	1.10	.250	82.10	12.84	1.60	7.04	22.73
5	Hominy; blood-flour; bone-meal	79.27	15.49	2.94	1.11	.205	81.67	14.18	1.32	7.17	18.47
6	Hominy; blood-flour; sodium phosphate.	80.55	14.56	2.72	1.12	.234	81.16	13.98	1.61	7.69	20.90
7	Check lot	78.80	16.83	1.99	1.20	.262	80.40	9.38	1.57	7.13	21.83
	EXPERIMENT III										
1	Corn	76.70	17.07	4.95	1.14	.313	80.69	21.24	1.83	6.68	27.46
2	Check lot	80.32	14.37	2.11	1.12	.249	82.05	10.72	1.73	7.79	22.23
3	Hominy; blood-flour; bran-extract	79.78	15.79	3.41	1.11	.249	82.60	16.86	1.58	7.03	22.43
4	Hominy; blood-flour; bone-flour	77.18	16.01	3.92	1.14	.318	80.33	17.18	1.99	7.12	27.90
5	Hominy; blood-flour	77.84	17.00	3.91	1.07	.294	81.01	17.64	1.73	6.29	27.48

The kidneys from the corn-fed pigs, (Table XXVII, page 292), contained less water and more fat, in both Experiments II and III, than from any other lots. In both experiments they were high in protein and in ash. The phosphorus content of the kidneys of the young pigs of Experiment III, was much higher in the corn lot, the the bone-flour lot, and the low-phosphorus lot, but lower in the check lot, than in the corresponding lots of older pigs in Experiment II.

The kidneys of the bran-extract lots were, in both Experiments II and III, lower in fat than any except the check lot; were high in percent of water, and higher than any other lots in percent of water in the fat-free meat; were low in fat in the water-free meat; low in ash, and in proportion of ash to protein.

The bone-meal ration produced kidneys that were high in fat, both on the basis of the whole meat and the water-free meat, and in both Experiments II and III were higher in fat than in the bran-extract, the low-phosphorus, and the check lots.

The livers of the corn-fed lots,(Table XXVIII, page 294), were characterized by only two conditions that hold good through both experiments; in each they are comparatively low in ash and in phosphorus.

The livers of the bran-extract lots are characterized by being high in percent of phosphorus, and high in percent of phosphorus in the ash. Compared with the bone-meal lots, the bran-extract lots, No. 4 in Experiment II, and No. 3 in Experiment III, were the higher in both experiments in water, protein, fat, phosphorus, water in the fat-free meat, fat in the water-free meat, and phosphorus in the ash. The phosphorus and ash in the protein were higher in the bone-meal lots.

Since water, fat and protein were all higher in the livers of the bran-extract lots than in the bone-meal lots, this would indicate a higher glycogen content in the livers of the latter, or errors in analytical work.

The livers of the low-phosphorus lots, No. 6 in Experiment II and No. 5 in Experiment III, were high in percentage of protein and ash, but low in water and phosphorus, and in the proportion of ash and of phosphorus to the protein.

TABLE XXVIII: ANALYSES OF LIVERS.

EXPERIMENT II.

Lots	Rations	Water	Protein	Fat	Ash	Phosphorus	Water in fat-free meat	Fat in water-free meat	Proportion of phosphorus to protein	Proportion of ash to protein	Phosphorus in ash
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
1	Corn	74.24	18.83	2.81	1.27	.320	76.39	10.91	1.70	6.74	25.20
2	Hominy; blood-flour; bran-extract, (larger amount)	73.52	17.19	2.46	1.37	.356	75.37	9.29	2.07	7.97	26.00
3	Hominy; blood-flour; lecithin	71.98	18.72	2.90	1.29	.364	74.13	10.35	1.94	6.89	28.22
4	Hominy; blood-flour; bran-extract, (smaller amount)	71.96	20.13	3.01	1.32	.364	74.19	10.74	1.81	6.56	27.58
5	Hominy; blood-flour; bone-meal	71.81	19.45	2.65	1.39	.361	73.76	9.40	1.86	7.11	25.97
6	Hominy; blood-flour; sodium phosphate	72.05	20.58	2.86	1.34	.324	74.16	10.20	1.57	6.51	24.18
7	Check lot	71.48	14.61	1.84	1.17	.291	72.82	6.45	1.99	8.01	24.87
	EXPERIMENT III										
1	Corn	70.77	16.08	2.32	1.21	.338	72.45	7.94	2.10	7.52	27.93
2	Check lot	71.21	18.12	3.01	1.33	.338	73.42	10.46	1.87	7.34	25.41
3	Hominy; blood-flour; bran-extract	71.65	20.44	2.49	1.30	.367	73.48	8.78	1.80	6.36	28.23
4	Hominy; blood-flour; bone-flour	70.43	19.31	2.03	1.30	.366	71.90	6.87	1.90	6.73	28.15
5	Hominy; blood-flour	70.64	20.97	2.26	1.34	.346	72.27	7.70	1.65	6.39	25.82

CONCLUSIONS FROM EXPERIMENTS II AND III.

Experiment II, Lot 1, (corn alone). By reference to Table XIX, page 271, we see that Lot 1 received the lowest proportion of proteid to non-proteid food, the smallest amount of calcium and of sulphur, but more phosphorus, than any lot except Lot 2, (larger amount of bran-extract). The ration contained a greater excess of mineral acid over mineral base than any other.

This ration of corn alone produced the least increase in live weight, (Table XX, page 278), the smallest and weakest bones, (Table XXV, page 288), the smallest percent of liver, kidney and muscle in the increased weight, (Table XXIV, page 285), the smallest gain in the weight of the heart, and the largest increase in the leaf-lard and back-fat, (Table XXIII, page 284).

The weakness of the bones is attributed principally to the deficiency of corn in calcium and in protein, and to the considerable excess of mineral acid over mineral base in this feed. The great excess of magnesium in proportion to calcium is also probably a factor in the inefficiency of corn to produce bone.

The low proportion of proteid tissues and high proportion of fat in the increase is due mostly to the low protein content of this feed; and proteid increase was also doubtless interfered with by the excess of acid mineral elements.

Experiment III, Lot 1, (corn alone). The corn ration, in Experiment III, (Table XIX, page 272), was low in protein and calcium but high in phosphorus in comparison with these other rations. It seemed to be poorly adapted to the production of tissue, the gains in live-weight, muscles and internal organs being generally very low. It was better adapted to the production of fat, of lungs, and of ash in the bones than to other purposes. (Table XXIII, page 284). We should bear in mind, however, that corn is a very poor bone food, and that it excelled in this experiment only because the other rations were still less efficient. The high fat production seems to be due principally to the low proportion of protein in the ration, the animal being forced to make fat through its inability to construct proteid growth from the nutrients provided. The low calcium content of the ration was quite unfavorable to bone formation. The comparative abundance of phosphorus and the deficiency in protein, which limited the use of phosphorus in proteid increase, accounts, in part, for the considerable gain which there was in the ash of the bones, the ash per cubic centimeter of volume being higher than in other lots. (Table XXV, page 288).

In both Experiments II and III the proportions of lungs, leaf-lard and back-fat were all higher in the increase made by the corn ration than with the balanced rations, but the proportions of kidneys and muscles in the increase with the corn ration were lower than with the other rations, which contained more protein.

In Experiment I, (Table XI, page 261), the same relations exist in the development of these organs, between the corn rations and the balanced rations, except that the increase in lungs is comparatively less than in the balanced rations.

The association of small kidneys and muscles, with thick back-fat and heavy leaf-lard, in the lots which received corn alone, is apparently simply the result of the lack of protein in the ration.

The muscular tissue produced from corn was characterized by high fat and low protein contents, and by high water content of the fat-free meat.

The kidneys of the corn-fed pigs were low in water content, and higher in fat than the kidneys from other lots.

The livers of the corn-fed pigs were low in ash and in phosphorus.

The younger pigs used in Experiment III did not thrive on this corn ration nearly so well as did the older pigs of Experiment II.

Experiment II, Lot 2, (hominy, blood-flour and bran-extract, larger amount). This lot which received the larger amount of bran-extract, received about the same organic nutrients as Lot 4, which received a very much smaller amount of bran-extract; hence we may look to differences in the mineral nutrients for explanation of differences in results. The lot which received the larger amount of the extract received in its ration more mineral nutriment than the lot receiving less of this extract, and since the balance of mineral acid to base in bran-extract is in favor of the basic elements, ration No. 2, containing the larger amount of this food, contained a smaller excess of mineral acid over mineral base than than did ration No. 4. These observations are all in favor of Lot 2; but this lot of pigs was constantly in discomfort, and the results show that something was wrong with the ration. The bones of the pigs were less in volume, (Table XXV, page 288); the ash per cubic centimeter of volume of bones was less; the breaking strength of the bones was much less, and the measurements of length and diameter were less where the larger amount of bran-extract was used.

The gain in live weight, heart, lungs, leaf-lard, muscles and back-fat was less, and the gain in liver, spleen and kidneys decidedly greater where the larger amount of the bran-extract was used. (Table XXIII, page 284).

These differences seem to be due to the great excess of magnesium over calcium in bran-extract, which resulted in a withdrawal of calcium from the body; it is possible that the large amount of phytin in the bran-extract also contributed to the unfavorable results, though at least in moderate quantities this compound is a valuable nutrient.

Experiment II, Lot 3, (low-phosphorus basal ration and small amount of lecithin). This lot, which received a small amount of pure lecithin in the feed, was composed of but a single pig, and we hesitate to draw conclusions from results with a single individual; we would call attention, however, to the facts that this ration, differing from that fed to Lot 6 only in that the latter received as sodium phosphate the same amount of phosphorus that the former received as lecithin, produced greater gain in live-weight at a lower expenditure of food and the percent of gain in heart, liver, spleen, leaf-lard and muscles, and in the ash, volume, ash per cubic centimeter of volume and breaking strength of the bones was also greater with this ration containing lecithin.

The gain in the lungs and kidneys was less where lecithin was fed than where the phosphorus was fed as sodium phosphate. These facts may indicate high proportion of storage of the nutrients in the body and, in consequence, low eliminative activity.

These observations, coupled with the more rapid and economical gain in weight, and the greater increase in the growth of muscles, visceral organs and bones, might be considered to indicate that the lecithin had exercised a very favorable influence in the animal economy. These deductions are suggested because, though this evidence is insufficient for their establishment, subsequent work by the author at the Ohio Station sustains these observations. They appear to be in harmony with the facts. It may be well, however, to call attention to the fact that these results were obtained with rations which were very low in phosphorus. We have as yet no evidence to warrant the supposition that any such results would have attended the addition of lecithin to a normal ration, or that lecithin is the only organic phosphorus compound possessing the same capacities. Ten percent of the phosphorus of this low-phosphorus ration was in the shape of lecithin.

The pig selected for this ration was not apparently in any way a superior individual. There was no difference of opinion on this point among those who observed the progress of the experiment.

The muscles of the pig which received lecithin were characterized by a high percent of water and of ash; and of phosphorus, in the tissue as a whole, and also in the ash of the muscle.

The kidneys were low in water content.

The liver, like the muscles, was high in its content of phosphorus, both in the tissue as a whole and in its ash.

Experiment II, Lot 4, (smaller amount of bran-extract) **and Lot 5,** (bone-meal). Lot 4, which received the smaller amount of bran-extract, gained in weight rapidly and economically, (Table XX, page 278), and there was every evidence that these pigs were well nourished.

The most instructive comparison is between this lot and Lot 5, which received bone-meal with its basal ration. The proportion of protein to non-proteid organic nutrients was the same in both rations. The most marked differences are in the phosphorus compounds used as supplements. In Lot 4 the bran-extract contained a very large amount of phosphorus in an organic combination known as phytin. The ration fed to Lot 5 contained somewhat more phosphorus than the above, but two-thirds of it was inorganic bone phosphate.

This bone-meal ration contained six times as much calcium, but only one-third as much magnesinm, as the bran-extract ration, No. 4, and also contained a smaller excess of mineral acid over mineral base.

Lot 4, which received the organic phosphorus compound from wheat bran, made greater and more economical growth and produced a larger percentage of muscle and fat in the increase, (Table XXIV, page 285), but the development of the bones was very decidedly less, (Table XXV, page 288), being excelled in volume, total ash, ash per cubic centimeter of volume, breaking strength and length, and in one of the two transverse diameters.

The fact that the bone-meal lot received the most calcium and phosphorus explains in part their greater development of bone, but renders still more decisive their failure to develop muscle. Bone-meal seems not to be able, as is bran-extract, to contribute to the development of proteid increase.

The lower potassium content of the bone-meal ration, (Table XIX, page 271), may be a factor in its inferiority for muscle production, since potassium is a prominent constituent of the ash of flesh.

We should also bear in mind that the bone-meal lot ate 14 percent less feed than the bran-extract lot, No. 4, but that at the same time the bones produced were both denser and stronger.

The bone-meal ration contained more than twice as much phosphorus as the low-phosphorus ration, No. 6, but produced a smaller proportion of muscle in the increased weight. This is probably due most largely to the unavailability of the phosphorus of bone for muscle

formation, but partially to the lowered digestibility of the protein of this ration because of the presence of phosphorus in this condition. This latter fact has been observed by a number of investigators, among them LeClerc and Cook*.

Experiment III, Lot 3, (bran-extract) and Lot 4, (bone meal). In this experiment the bran-extract ration was consumed in the same amount as the bone-flour ration, and the nutritive ratio and amount of protein were the same. These rations differed, however, as to the amount and kind of ash constituents, the bran-extract ration containing decidedly more potassium and phosphorus but very much less calcium. (Table XIX, page 272).

This excess of calcium in the bone-meal ration increased the amount and proportion of ash in the increase, and the ash per cubic centimeter of volume of bone, but seems not to have been of other conspicuous advantage. (Table XXIV, page 285).

The deficiency of potassium and phosphorus, as compared with the bran-extract ration, is reflected in the gain in live-weight, muscle, heart, liver, spleen, lungs and kidneys. In each case the bran-extract lot exceeded the bone-flour lot. (Table XXIII, page 284). What then did the bone-flour lot do with that amount of nutriment which the bran-extract lot made into the greater amount of protein in the increase? Judging by appearances we would say that they made it into fat, for they looked very much fatter, and in accordance with this idea we find that the leaf-lard was heavier, and the back-fat thicker in this lot. (Table XXI, page 281). There was the same amount of phosphorus in the hominy and blood-flour in both the bran-extract and the bone-flour rations, (Table XIX, page 272), but the phosphorus in the bran-extract was greater in amount than the phosphorus in the bone flour, and was present in a very different compound, in the former case being mostly phytin, and in the latter case being mostly the tri-calcic salt of phosphoric acid.

While this bran-extract produced maximum muscular increase, the muscles were characterized by a lower phosphorus content than is found in any other lot.

The kidneys of the bran-extract pigs were very low in fat, and high in water, both in the tissue as a whole and in the fat-free substance. The kidneys were also low in ash in the tissue as a whole, and also low in proportion of ash to protein.

The livers of this lot were characterized by high contents of phosphorus, both in the tissue as a whole, and in the ash.

* LeClerc and Cook: Journ. Biol. Chem. vol. 2, p. 203.

The addition of bone-meal to the low-phosphorus ration increased the proportion of ash to protein in the muscles produced, by decreasing the percentage of protein. The percentage of phosphorus was not increased either in the muscles, or in the ash of the muscle.

The kidneys were characterized by a high fat content.

Experiment II, Lot 6, ("low-phosphorus lot," basal ration and small amount of sodium phosphate). The "low-phosphorus" ration, No. 6, was also low in calcium, (Table XIX, page 271), but did not contain, as apparently did the corn, and bran-extract rations, an excessive proportion of magnesium to calcium.

There are in the results from this ration no such marked indications that the pigs suffered from a lack of phosphorus as with the same ration in Experiment III, where the pigs were considerably younger, and where no sodium phosphate was fed with the hominy and blood-flour.

The 43.5 grams of phosphorus fed to this low-phosphorus lot as sodium phosphate constituted 10 percent of the total amount of phosphorus in the ration. Its ready solubility may have given it a value out of proportion to its amount, in comparison with the total phosphorus in the ration.

Comparing this low-phosphorus lot, No. 6, with the bran-extract lot, No. 4, we find that the gain in weight was essentially the same, and the efficiency of the two rations to cause gain in weight was the same, (Table XX, page 288). We do see some evidence of the lack of phosphorus, calcium and potassium, in ration No. 6, however, in the smaller gain in the volume and ash of the bones, in their lower breaking strength, (Table XXV, page 288), and in the somewhat smaller proportion of muscle in the increase, (Table XXIV, page 285).

Shotes with well-grown bones and muscles seem to be able to stand a moderate shortage in the ash constituents of the ration for 56 days, without any marked effect. The younger pigs of Experiment III felt the lack of the ash constituents of this ration, the same except for the lack of the sodium phosphate, very much more keenly.

Experiment III, Lot 5, ("low-phosphorus" basal ration). The "low-phosphorus" ration, No. 5; (Table XIX, page 272), consisting of hominy and blood-flour, contained decidedly less calcium, potassium and phosphorus than either the bran-extract or the bone-flour rations. The food was also eaten in smaller amount, but had the same nutritive ratio as these other two. In potassium and phosphorus this ration was much lower than the corn ration, but was decidedly higher in protein and calcium. The greater

quantities of calcium and of protein, however, did not compensate for the lack of phosphorus and potassium, for the gain in the ash of the bones was almost nothing; very much less than in the corn lot. (Table XXIII, page 284). The ash per cubic centimeter of volume of the bones was less than with other lots, and was much less than in the check lot, which was not fed. (Table XXV, page 261).

The most interesting conclusion to be drawn from this experiment, however, is that the proportion of muscle in the increase was not greater in the bone-flour lot than in the low-phosphorus lot, No. 5, (Table XXIV, page 285), thus reinforcing our conclusions drawn from Experiment II that the phosphorus of bone is not of appreciable assistance in the formation of muscle. In both these experiments there is a slightly greater proportion of muscle in the increase with the low-phosphorus lot than with the bone-meal or bone-flour lot, but in both cases a less proportion than with the bran-extract lot.

The most noticeable effect of this low-phosphorus ration on the chemical composition of the animal was the low proportion of ash and of phosphorus to protein in the livers.

GENERAL SUMMARY

The limitations imposed by the food supply affect not only the amount, but also, within limits, the composition of the growth produced.

The mineral elements of foodstuffs appear to enter largely into the determination of their specific effects on the development of animals.

Rations of corn balanced by proteid supplements from sources other than corn, appear to be more palatable and more efficient to cause growth than rations of corn and corn products only.

The deficiencies of corn as a food for growing animals appear to be a lack of protein in proportion to non-proteid organic nutrients; a marked lack of calcium, and a less pronounced shortage of phosphorus; an excess of magnesium in proportion to calcium, and a deficiency of basic mineral elements as compared with acid mineral elements.

These deficiencies are all susceptible of correction by the use of supplements. We know of no reason why good sound corn should be entirely withheld from any animal at any time when it needs food.

The specific effects of corn as an only food, as evidenced by the growth of young swine, are in general, a retarded development of proteid and bony tissues, and an over-development of fatty tissue. This results in the production of fine-boned, poorly muscled, undersized and over-fat animals, which reach their limit of growth prematurely, and which are characterized by less than normal breeding capacity. Impaired fecundity seems to result from discouragement of proteid increase generally, and from the lessened circulation of blood in the female reproductive organs, this last being caused by pressure of the excessive amounts of internal fat which accumulate about these parts.

With hogs fed on corn alone, the bones, muscles, liver, kidneys, lungs, heart and spleen all compose an abnormally small proportion of the increase in weight, and fat composes an abnormally large part of the increase.

The muscles of corn-fed pigs are high in fat, and low in protein and in water; but the percentage of water in the fat-free meat is decidedly high. The proportion of ash to protein in the flesh of corn-fed pigs, however, is not low.

The livers of corn-fed hogs are small and low in ash and in phosphorus.

Compared with rations containing more protein, corn produces small, fat kidneys. The low-proteid corn ration makes less extensive requirements, and so produces less development of the kidneys than other rations containing more protein. This has a bearing on the feeding of growing animals. The eliminative functions of the body will not reach full development if the animal be reared on a minimum protein allowance.

The bones likewise are small, and lacking both in density, as indicated by ash content, and in breaking strength.

Corn alone as a food for swine lacks palatability. Hogs will eat very much more of mixed rations, and make much greater, more economical and almost invariably more profitable gains in weight, than from corn alone.

Corn by itself is more nearly a perfect food for maintenance than for growth. The younger the animal, or the greater the amount or proportion of protein in the increase in a given time, the less nearly is corn a perfect food for animals.

In comparing rations of corn alone with rations of corn supplemented with wheat middlings, linseed oil meal, tankage, soy beans and germ oil meal, all rations except the corn being compounded to have the same nutritive ratio, the proteid increase was, in general, in accord with the organic phosphorus content of these rations.

The development of fat was in the inverse order; that is, where the protein of the ration was accompanied by the proper mineral elements, a certain amount of proteid tissue was produced; where the protein of the food lacked the necessary mineral accompaniments, its nitrogenous portion was excreted, and the remainder used for the production of fat and energy. The tankage, linseed oil meal, and soy bean rations were about equally palatable and effective to cause gain in weight.

Tankage and linseed oil meal are about equally profitable supplements to corn at the prevailing prices of recent years.

Soy beans may be grown in the Corn Belt and used with profit in pork production, though the supply of beans on the market is sufficient only to satisfy the demands for seed, at seed prices.

Wheat middlings and germ oil meal are neither so palatable, nor so efficient, nor so profitable, as supplements to corn in pork production as are tankage and linseed oil meal.

The principal organic phosphorus compound of wheat bran, known as phytin, is a valuable nutrient. It contributes to the development of proteid tissues generally, including muscles and visceral organs, and also to the growth of bone.

Phytin was fed as a water-extract of wheat bran, the solution of the phytin being accomplished principally by the slight acidity produced by bacterial fermentation. This bran-extract is characterized by a very high magnesium content, especially so in relation to calcium. The antagonism between these elements in their effect upon the tissues renders this disproportion a matter of importance, since it exists not only in wheat bran and wheat middlings, but also in corn and in other grain feeds.

The excess of magnesium in proportion to calcium in foods appears to cause a counteractive liberation of calcium from the tissues, especially the bones, and thus we may produce malnutrition of the bones merely by the excessive use of a food characterized by disproportionate amounts of magnesium and calcium.

The ash of the bran-extract used in these experiments was, as is the ash of bran, about neutral. Hence this removal of ash from the bones was not acidosis, though the effects upon the bones was the same. Water-extract of wheat bran is a very palatable food. Its nutritive value was most pronounced when used in moderation; the pathological consequences appeared when fed in larger amounts.

"Bran disease," "shorts disease," or "miller's horse rickets" appears to be caused, in part, by the excessive proportion of magnesium to calcium in wheat bran and shorts.

The muscles of pigs which received bran-extract were characterized by a low phosphorus content, though the ration itself was rich in easily assimilable phosphorus.

The livers of pigs which received bran-extract were high in phosphorus, both in the tissue as a whole and in the ash. The kidneys from pigs which received bran-extract were low in fat and in ash, but high in water content.

Lecithin was added to a low-phosphorus basal ration in such quantity as to contribute 10 percent of the total phosphorus of the ration. This ration was compared with another in which the same quantity of phosphorus in the form of sodium phosphate was added to the basal ration.

Lecithin seems to be a valuable nutrient. The ration containing this compound appeared to be especially palatable and excelled in the rapidity and economy of the gain produced.

The muscles, livers and kidneys produced by the lecithin ration all contained a high percentage of phosphorus. Subsequent work by the author at the Ohio Station shows that phosphorus in the same condition as in lecithin contributes to the organic phosphorus content of brain and muscle.

The phosphorus of bone-meal appears not to add to the muscle-producing capacity of a low-phosphorus. ration; in fact, there is some evidence to suggest that it interferes, to a slight extent, with the utilization of protein. Bone-meal, however, contributes directly and conspicuously to the ash, density and breaking strength of bone.

Bone-meal does not diminish the tendency of pigs fed on a low-phosphorus ration to make fat from the protein of the food.

The muscles of the pigs which received bone-meal were lower in ash, and percentage of phosphorus in the ash, than the muscles of pigs which had received a low-phosphorus ration lacking the bone-meal.

A ration which was very low in phosphorus, potassium and calcium, but which contained an abundance of protein and other organic nutrients, made very little increase in muscles and in bone ash.

The ration lowest in phosphorus produced muscles which were especially low in water, both in the whole tissues and in the fat-free substance; high in protein, ash and phosphorus, but low in the proportion of phosphorus to protein.

The phosphorus compounds of the food do not directly favor fattening, as they do muscular growth, but they may do so indirectly, through affecting the general health of the animal. On the other hand they are apt to discourage fattening in growing animals through making possible the normal use of the nutriment in the formation of proteid increase.

The general result of this work is to call attention to the importance of the ash constituents generally and to phosphorus in particular in the rations of growing animals.

If we are to use corn as the principal food for animals which are being fed either for growth or production of other proteid increase, such as milk and eggs, we can hope for the greatest success only by feeding with the corn, supplements that are richer in protein, calcium and phosphorus; higher in proportion of basic minerals to acid minerals, and lower in proportion of magnesium to calcium.

A BRIEF HANDBOOK OF THE DISEASES OF CULTIVATED PLANTS IN OHIO

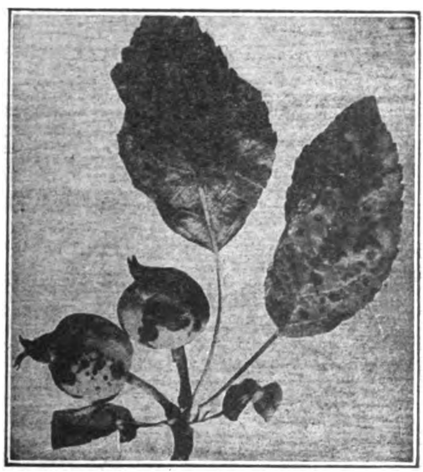
The Station

OHIO Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., MARCH, 1910.

BULLETIN 214

Revised Edition of Bulletin 121



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BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 214 MARCH, 1910.

A BRIEF HANDBOOK OF THE DISEASES OF CULTIVATED PLANTS IN OHIO

By A. D. SELBY

INTRODUCTION

The idea of disease is not a simple one, though it may seem so before trying to define it. In reality the term "disease" as applied to plants, means any change in that plant toward reduced vigor, etc., from the ordinary or average behavior. To put it another way, a plant is said to be "diseased" when it shows any deviation from the ordinary or average behavior of that plant in respect to appearance, growth, color of bark, foliage, fruitfulness, time of dropping leaves or length of life; in short, when the plant fails to conform to those averages which we have established by extended observation for the species and variety in question, we say it is diseased. Under such a general definition, variegated or purple hued sports would be included, although potentially rather than actually in diminished vigor. Variegated sports succumb easily to parasitic attack and, as later investigations show, are really suffering from enzymatic troubles.

The more usual symptoms of disease are marked by evident differences in the plant. The leaves become spotted, curled or discolored, or may even drop prematurely; the fruit may develop unevenly or be marked by decayed spots, or the twigs may blight, wilt or die. In all such cases we have a manifest loss of vigor and reduced profit. Yet we may not attribute all these to parasitic fungi or to parasitic insects; purely physical or chemical agencies may be at the bottom of certain troubles. Plants may be asphyxiated by too much water which excludes the air supply; they may likewise, be strangled by escaping gases, especially in the case of city shade trees, or their protoplasm may be attacked by chemi-

cal agents such as strong acids and alkalis. Quick growing pla appear to fall in drought, as with cucumbers when started duri a period of excessive rains. Plants, and especially trees, may locally injured by winter freezing, by hail, by overbearing with haustion of water supply, and by a variety of causes.

While we must keep our minds open to these varying causes impaired vigor, by far the larger number of the diseases describ in this bulletin are directly attributable to parasitic fungi whi attack the plant or host in some vital part and rob it of its substan The conditions of injury arising from the attacks of insects alo are not included. These fungus parasites of particular plants are differing sorts, which produce, each, its more or less particu effects. It must follow, therefore, that the diseases produc differ in nature and that the names applied will vary according The names are not simply blight, rust, etc., indiscriminat applied—they are given with reference both to the parasite and effect on the host plant.*

Parasitic fungi and bacteria which cause disease, being plan though of lower class, have differences among themselves which m be clearly designated and defined. The names applied to them a accompanied by specific and generic descriptions which mark the sort as definitely as do the descriptions on higher plants su as ferns, flowering plants and trees. The extreme minuteness the parts of parasitic fungi and bacteria make necessary the use the microscope in their description and detection. The parts call spores which reproduce these minute plants have special form, si etc., by which these are recognized when found.

The agencies for the spread of parasitic diseases are tho operations in which we engage or those which surround and envel the plants as well as ourselves. Light spores will be carried currents of air like particles of dust. All spores or germs of the lower plants may be carried by numerous agencies such as insec higher animals, and man. They will also find entrance into plan by whatever openings exist at the time. The epidermis of a green le or stem has breathing pores or stomates in it; the leaves of musta plants have water pores in them and wounded plants have the fresh openings to invite the entrance of the disease conveyi spores or germs.

The remedies for plant diseases are based upon the charact and life history of the particular parasitic growth with which have to deal and upon the nature of the host plant itself—so hosts being very different from others in respect to permitting sprays of fungicides or insecticides. Common sense inferences a

* See naming of diseases.

always of use in dealing with plant diseases. If the soil is too wet, drain it; if late growth predisposes to winter injury, avoid such growth; if overbearing weakens plants, prevent it by thinning the fruit.

The philosophy of seed treatments is stated under diseases which infest the seed; that of soil treatments or disinfection, under soil infesting disease, and the general doctrines of sprays, fungicides, etc., under that heading further on. The progress made in plant disease prevention throughout the world during the period of about 26 years which has elapsed since the discovery of Bordeaux mixture in France shows how well adapted that discovery was to the needs of the times.

The progress made in recent years in the study and control of plant diseases has been made possible by the agencies recently developed in the United States in the Agricultural Colleges, the Agricultural Experiment Stations and the United States Department of Agriculture. It is not expected that this advance in our knowledge of the diseases of plants or of the methods of disease control will soon wane. Efforts like the present one to present briefly the doctrines of disease and the philosophy of disease control together with brief descriptions of prevailing diseases in our state, have for their purpose the wider dissemination of the body of present day knowledge in these lines. Such a statement will not close the march of progress nor make less the need for more knowledge. It is hoped that cultivators of plants, whether farmers, gardeners, horticulturists or florists will find suggestive statements of information in the bulletin by which they can direct their own efforts to better advantage and correct or broaden their own inferences from observed conditions about them. All such results will not only increase the need for more knowledge, but will furnish impetus to the movements by which we will gain the desired information.

In the preparation of the revised edition of the original Bulletin, No. 121, the general part immediately following this introduction has been considerably enlarged and brief discussions are now given concerning groups of plant diseases as well as those concerning parasitic fungi. It is fully apprehended that the host plant is the center of practical as well as economic interest and these statements concerning enzymatic diseases as in the case of peach yellows and mosaic disease of tobacco, diseases transmitted in the seed, soil infesting diseases, and the relation of the spread of certain diseases to leaf biting insects are given as aids in mastering the principles involved. The same aim has governed the discussions upon wounds

and wound fungi so especially dangerous with orchard, shade forest trees. Somewhat fuller discussion of atmospheric age as affecting the occurrence and spread of plant disease remedies for diseased conditions and of the application of the in combatting diseases and a presentation of storage troubles also seemed desirable. Special attention is called to the host in the matter of breeding or selection for disease resistance a the contrasts offered by American and European points of vie plant disease study.

ACKNOWLEDGMENTS

The illustrations in this bulletin have been drawn from sources than in the previous hand book. A large number, incl perhaps, a larger portion of the cuts, are taken from previous lications of this Station by Weed, Miss Detmers, and the w small cuts have been at times made from certain larger illustra while with others only portions of the original cut have been us

A great many of the illustrations are new, and I am deepl debted to Messrs. J. M. Van Hook and Thos. F. Manns for ma the photographs from which these have been made. I am als debted to Professors Halsted of New Brunswick, N. J., and A son of Ithaca, N. Y., and to the Bureau of Plant Industry of the Department of Agriculture for many favors in the matter of which are used in the Bulletin. Figures 24, 25, and 26 are Dr. Freeman's "Minnesota Plant Diseases." For permissi reproduce these, I am indebted to Prof. Frederick E. Clemen the University of Minnesota. In all cases where it is not othe obvious, it has been the aim to state the source of the illustratio the descriptions. The same applies to illustrations reprod from standard works.

In many matters connected with recent investigations o Department bearing upon diseases included in this present bul and upon current examinations, I am under many obligatio Thos. F. Manns, Assistant Botanist, who has rendered very assistance.

GENERAL PART I

CONCERNING PLANT DISEASES IN GENERAL

As defined in the introduction, a plant is called diseased when it fails to show normal vigor and normal condition of its parts. The manner of disease attack is extremely varied and the conditions set up as a result of disease are accordingly of many different kinds. We learn to recognize disease by the symptoms shown in the plant; these symptoms will at times be readily interpreted and on other occasions they will prove misleading. Nothing is plainer than the necessity for continuous observation of growing plants if one is to be in a position to interpret the symptoms of disease.

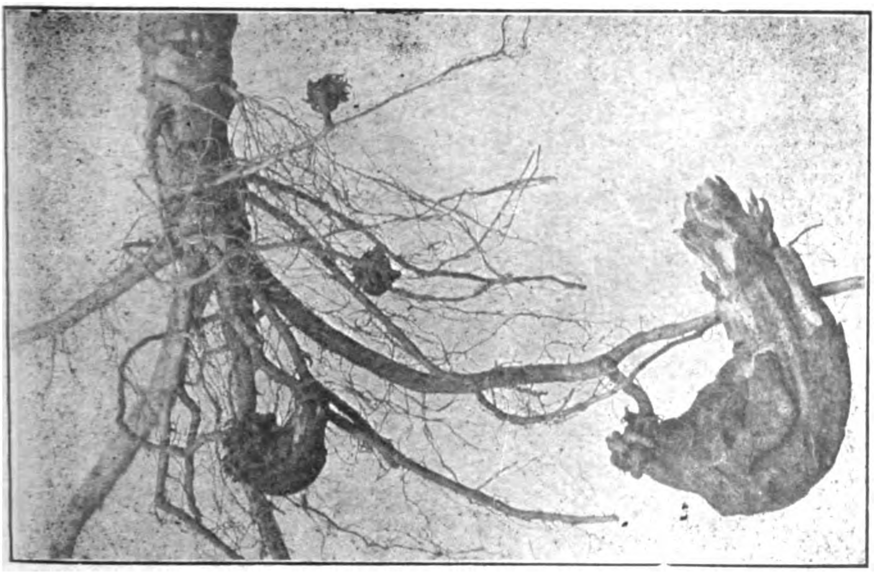


Fig. 1. Roots of white burley tobacco plant attacked by broom-rape. Each of these masses attached to the root shows beginning of the plant which will grow up in larger dense form, and produce an abundance of blossoms and seeds but no leaves. Each one of these must have started from a buried seed of the broom-rape, *Orobanche Ludoviciana* Nutt.

Diseased conditions may be due to the very obvious attacks of certain parasitic seed plants which lack leaf-green or chlorophyll in their tissues and must subsist on other plants somewhat after the manner of parasitic fungi. The dodders which attack the clovers, alfalfa, onions, etc., belong in the class of parasitic seed plants of the genus *Cuscuta*. Their seeds are liable to be harvested with the

seeds of clover or alfalfa and to be present in the commercial seeds. While these have been treated in the weed manual they require mention here. The seedling plant of dodder first forms a root and sends upward a whitish stem which twines about the clover or other stem, and sends sucking branches into the stem interior. These "haustoria" extract food material from the clover stem—that is they rob it of its own substance. Upon the formation of such organs the root of the dodder dies off and the future existence of these twining, strawlike stems is at the expense of the host plant.

A similar state of parasitic existence is found in the broomrape tribe whose very small seeds are scattered through the soil. Such a broomrape is well known on hemp, and the same hemp broomrape also attacks tobacco in Kentucky and possibly in our state. We have found another broomrape attacking tobacco in one district of Brown county, Ohio, and the illustration shows its appearance on the tobacco roots.

When the leaves of a plant are attacked these show the direct effects; the symptoms of parasitic leaf diseases are usually localized injury resulting in spotting and often in browning of the leaf parts. Leaves may dry up somewhat slowly and drop to the earth, and yet the leaf tissues are simply dried up. Such conditions may result from late frost as upon shade, fruit, or ornamental trees. A most interesting case was once studied upon catalpa as a result of a frost in May. In that case the drying up was none the less to be expected at that time.

An even more interesting case of leaf drying and dropping was upon young catalpa trees in a nursery caused by the attacks of a root-rot fungus, *Thielavia*. Owing to the death of many of the rootlets and finer roots as a result of the root-rot trouble, the leaves of these young trees dried up prematurely in August and September and the leaves all dropped off. Thus we may have leaf dropping as a result of frost, injury by hail, root impairment or localized parasitic attack.

LEAF SPOT AND SHOT-HOLE EFFECTS

Leaf-spot symptoms are everywhere abundant and are really of very diverse origin. In any example in which the leaf tissues are locally invaded by a parasitic fungus we may expect evident effects. In the downy mildew troubles there may be wet-rot symptoms when the weather is moist, as in the case of *Phytophthora* or late blight attacking potato or tomato leaves; after the leaves have become badly diseased they may appear to die very suddenly because

the gradual invasion of the areas has been overlooked. In many other leaf diseases no such rapid multiplication or reproduction of the parasite is possible and limited dead patches or spots are the result. The leaf-spot disease of alfalfa, the various leaf-spots of apple and the conspicuous leaf-spot of the strawberry, the beet, the pea, etc., will be recalled. In these while the leaves are impaired as to usefulness they do not perish immediately and one may readily fail to estimate the injury at its real seriousness. In a few leaf troubles we have the spotting of the leaf followed by the formation of a separation layer in the leaf tissues between the parasitized and the healthy tissues. This results in "shot holes" in the leaves as is so very conspicuous in the shot-hole leaf disease of the plum and less conspicuously so on certain sour cherry trees. These leaf troubles are commonly very evident during rainy seasons and are preventable by spraying the foliage of the diseased plants at repeated intervals, thus keeping a supply of the fungicide on the leaves to arrest renewed spore development.

An interesting leaf-spot disease of the tomato is sometimes very damaging. This disease seems to have appeared in Ohio during the memory of many close observers. Like most leaf-spot troubles which are strictly due to parasitic fungi, this tomato disease has been worst in seasons of abundant rainfall. The same applies to the shot-hole disease of the plum and the allied leaf-spot of cherry. The explanation appears to lie in more favorable conditions for spore germination and for the growth or spread of the parasitic organisms which produce the diseased conditions. Biting or sucking insects also open the way for the entrance of parasitic diseases. (See later pages.)

LEAF IMPAIRMENT THROUGH FUNGUS COVERINGS

In addition to the leaf-spots or dead areas in leaves to which reference has just been made, we have most noticeable examples of the spread of the mycelium of certain powdery mildews over the leaf surfaces. Casual observers note that these spread over the leaves and stems of roses, over the leaves of lilac, of oak, of peach, of grape, of forcinghouse cucumbers, of bean and pea and upon other plants. While the development of these fungi or powdery mildews occurs often rather late in the season, they are nevertheless damaging to the host plant over which they spread. Above and beyond the interference with the leaf action the impairment of the photosynthetic or sunlight processes of the leaves of the plants by which all real increase in substance is made to the plants, these mildews develop sucking or penetrating organs of the threads of

the mycelium. These organs called haustoria penetrate the leaf epidermis and must do this for the purpose of food extraction—it is needless to add that all food extraction from the plant acts as robbery.

Furthermore, the mildew-covered leaves drop to the ground in fall and there afford the fungus the needed conditions for the development of the resting or winter stages of its course by which it is again ready to attack the plants the following season. Because so largely external in development these powdery mildews are usually comparatively easy of control.

WILT DISEASES—SEEDLING COLLAPSE

The stems or branches of plants may suffer from localized attack by parasitic fungi as well as from hail, insect attack and mechanical agencies. The symptoms which follow will be found characteristic. In certain ones as in the clover anthracnose and in the fusarium of clover stems, we have the lesions accompanied by discolorations in which the fungus occupies a subordinate place outwardly. On the other hand the spots or *sori* of the rusts upon grains and grasses and the spots caused by the anthracnose of wheat, oats, rye, etc. show commonly a crowded occupation of the area by the parasitic fungus.

There are many examples of the effects of such lesions. Fuller discussions will be found under the description of the particular diseases. The anthracnose of the bean as well as that of the pea are good illustrations where these attack seedlings. Even clearer symptoms come out in potato rosette where the fungus parasite at early stages of growth may kill off the stem attacked, while in later attack will cause such impaired development of the plant that stem or axial lengthening is arrested and a "rosette" appearance results. A still more striking arrest of stem elongation takes place in lettuce rosette wherein the roots are destroyed so largely by the fungus in the soil. (See soil infesting diseases.)

In cankers of branches upon orchard trees the final death of the immediate branch is preceded by a depressed area invaded by by the parasite.

PLANT DISEASES NOT BEYOND EXPLANATION

The old mystery attached to disease prevalence can scarcely be maintained in our day. We have worked out in recent years or had determined for us the causal relations between the ferment or parasite and the effects upon the host plant or crop. So far as we can now discover the reason for the spread of diseases, or of a

particular disease, is found in the specific disarrangements in the host plants. This discovery and announcement of these causal relations are undertaken that proper measures for the control of diseases may be finally devised and applied. We must always bear in mind that under favorable conditions plant diseases become epidemic and their rapid spread is to be expected.

The host plant, with its climatic adaptations and the parasites of our crops with their mutual adaptations to their hosts are biological factors which are capable of being influenced by prevailing atmospheric conditions. With cool, rainy weather we have brought about conditions favorable to certain parasitic diseases which will be inclined to spread while these continue. Other diseases spread under the conditions which favor them. The more rapid development of diseases of plants under these favoring circumstances is not beyond reasonable understanding; there is no mystery about it any more than in outbreaks of typhoid fever or diphtheria. By apprehending the differing conditions we may learn to separate the causal from the merely adventitious factors and thus be the better able to master the diseases which result.

While we may properly look upon infection by microscopic or other parasites as the general and usual cause of plant diseases, there are diseases of wide importance which arise from internal or physiological disarrangements in the plant. (See Enzymatic Diseases). In all cases whether of parasitic attack or of physiological disarrangement due to other causes, the host plant is weakened and predisposed to death.

GROUPS OF PARASITIC DISEASES

Parasitic diseases may be grouped in a way, according to the groups of fungi which cause them. This is helpful to the plant pathologist, though of limited practical guidance, since it requires microscopic study to determine the causal organisms. A more useful, limited grouping as is hoped, is proposed below and consists in making such groups or classes of diseases, as are descriptive of the general behavior. Such are seed infesting diseases, soil infesting diseases, root diseases, diseases of foliage, wound troubles, timber rots, etc. The great mass of diseases are treated under each host in the descriptive portion arranged alphabetically. The objects to be attained by this method of arrangement are obvious and call for no discussion.

NAMING PLANT DISEASES

Plant diseases are named with due regard to the symptoms and cause of the disease. In the case of enzymatic diseases wherein we have peculiar variations or yellowing of the leaves, the names given are more or less descriptive. The same applies to the diseases that are caused by freezing, hail, etc.

Parasitic diseases are named with regard to the organisms which cause the disease, or to the effects they produce in the host parts, that is, those diseases which result from attacks of the rust fungi, (*Uredineaae*), are properly called rusts; also the smutty, dirty conditions resulting from the attacks of the smut fungi, (*Ustilagineae*), are known everywhere as smuts; these are well known and destructive upon grasses and cereals. Thus we have smuts of oats, corn, wheat, broom corn, sorghum, millet, blue-grass, etc.

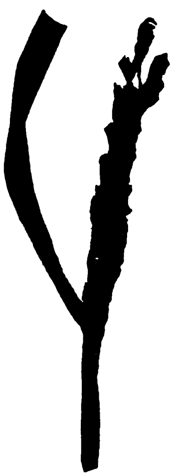


Fig. 2. Head or panicle of oats destroyed by loose smut. All the oat kernels and many of their surrounding parts have been converted into black, sooty (smutty) masses by the loose smut fungus, *Ustilago*.

The anthracnoses are produced by a definite class of fungi, (*Melanconiae*). The name anthracnose is applied to a disease of a given host caused by an organism of this group and the host name is usually retained, as the anthracnose of wheat, the anthracnose of rye, the anthracnose of raspberry, wherein the diseases are caused by species of this group of parasitic fungi. However, in the case of attack upon the fruit as in the anthracnose of apple, because of the bitter taste given to the fruit, we have the popular name bitter-rot; in a similar instance, viz., that of the anthracnose of the grapeberry, the discolorations of fruit are so characteristic that it is popularly called the birds-eye rot. With wheat, oats, rye, etc, the name is applied because of the organisms found. As stated in the preceding pages, we describe most leaf infesting diseases with regard to the effects the parasites have upon the host; thus we have the leaf-spot disease resulting from attacks of any one of a number of fungi, chiefly, however, belonging to the imperfect forms. The shot-hole fungus of the plum is a good illustration of the naming of a trouble from the symptoms produced.

Fig. 3. Section through an anthracnose spot (*acervulus*) of the cucumber anthracnose fungus (*Colletotrichum lagenarium*) showing the long, dark hairs (*setae*) of whose office we know little, the spore bearing branches (*fertile hyphae*) and the spores of this fungus. The members of that division of the commoner anthracnoses having setae in the acervuli are referred to the genus *Colletotrichum*, while similar ones without setae bear the genus names *Gloeosporium*, *Sphaceloma*, etc. (See anthracnoses of apple, grape, lettuce, wheat, oats, etc).

A considerable group of diseases are known as downy mildews. Among these we have the destructive potato late blight and rot, *Phytophthora*; also the cucumber disease, *Plasmopara*, as well as the

grape downy mildew and the common white molds of the mustard family. The powdery mildews by reason of the appearance upon the surface of parts attacked, are descriptively named "mildews." A definite system has been followed in most cases of naming plant diseases and I trust the results will not be altogether disappointing.

The differences between the species of parasitic or other fungi are as strongly marked as those of higher plants, even though microscopic examination is necessary to distinguish these characters; it shows, therefore, that a discriminative system of naming diseases has a secure foundation.

THE PLANT OR HOST IN RELATION TO DISEASE

As stated elsewhere only closely related plants are usually subject to attack by a parasitic organism, thus it happens that the tomato as well as the potato plants are attacked by the downy mildew or late blight fungus of the potato. In general the true parasites among our fungi are limited to a rather narrow range of host plants; thus we may expect the potato *Phytophthora* to attack several plants of the potato family (*Solanaceae*). The writer proved this same was true of the attacks of downy mildew (*Plasmopara*) upon a number of species belonging to the cucumber family (*Curcurbitaceae*). Since our cereal grains belong to the same great family as the grasses (*Gramineae*), we expect, and find that there is a development of the same diseases upon many of them and upon the grasses growing nearby. In this connection it must be remembered that clover and alfalfa are not grasses, but legumes.

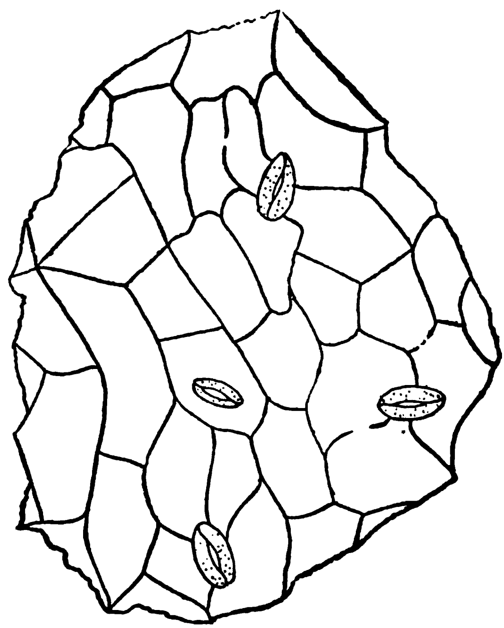


Fig. 4. A portion of the epidermis from the upper surface of a cucumber leaf, showing the breathing pores (*stomates*) surrounded by guard cells containing chlorophyll grains, much magnified. These guard cells, which control the opening and closing of the stomates, are the only epidermal cells that contain this green substance, the others being colorless.

The leaves of the host plant provided as they are with stomates or breathing pores, minute openings through the epidermal covering of the leaf, will be attacked through these openings. The spores

of parasitic fungi after germinating upon the leaf will likely gain entrance into the interior leaf tissues through these openings much more readily than by actual boring through the leaf epidermis.

The illustration, Fig. 4, shows how these openings are distributed in the epidermis of a cucumber leaf. These stomates are present in the leaf covering upon the outside of all green leaves and in the epidermis of young growing shoots. In addition to these stomates certain classes of plants such as the plants of the mustard family (*Cruciferae*), as cabbage, cauliflower, turnip, also the grape, fuchsia, impatiens, etc., are provided with water pores—marginal openings through which the excess water of the plants is excreted. These water solutions of various materials offer a means of growth for organisms, especially of the minuter forms. From the culture drops thus formed the parasite enters the leaf by the water pores. One of the most destructive known diseases of plants is the black-rot of cabbage, cauliflower, turnip, ruta-baga, etc. This is due to a bacterium which gains entrance very largely through the water pores just described. So we must bear in mind that the very avenues of transpiration or excretion, so essential to plant growth, are made a means of exposing the plant to the danger of parasitic invasion. This is analogous to the exposure of human subject to diseases of the respiratory organs. At every turn we find convincing evidences of the mutual adaptation of parasitic fungi to their host plants, in nothing more strongly marked than in the limitation of the species of plants attacked by a given parasite as discussed in the beginning of this paragraph. In view of the fact that so long as the leaves of a plant continue to function as leaves, these natural openings will be maintained, it will be seen that the risk of exterior infection from parasitic fungi is continuous for any given plant; it lasts for its whole growing period.

Fig. 5. Margin of cabbage leaf showing excreted water from water pores after cool night. These drops contain enough food for the growth of the black rot bacteria. The motile forms may swim through the water pores into leaf from such drops. Dead marginal areas on lower fragment show results of this bacterial infection. (After Smith).

THE PLANT'S PROTECTION AGAINST PARASITES

In the case of woody growths we have the development of corky epidermis or bark which seems primarily designed to protect the interior, living layer from invasions of this sort. In a similar

manner the external layer or bark of all growing plants, including herbs, is provided with a protective covering or epidermis. The skin of the apple or of the grape and the covering of the potato stem are all familiar and serve this function of protection to the inner tissues. In young plants there is retained the power of protective growth in response or resistance to parasitic attack; thus it happens that the potato scab organism induces the growth of cork cells on the outside of the potato and makes a roughness. The roughness is is not the scab fungus but the corky growth of the tubers in response to the scab attack. In a similar manner the attack of the scab fungus upon the apple results in the roughening of the apple skin through the development of more protective or wound cork. The most remarkable example of this multiplication of protecting or outer cells in response to the attacks of parasitic fungi is found in "leaf-curl" of the peach and in the pockets or "bladders" of the plum, where we have such a rapid multiplication of cells in response to the stimulus of the fungus as to bring about an entire transformation in the form and structure of the parts. While we may think of this abnormal development as the result of fungous growth, it is only indirectly so. It is in fact a response of the host to the stimulus of the invading fungus. The nature of the stimulus or excitation exerted by particular parasitic fungi is a highly interesting subject for investigation.

DISEASE RESISTANCE IN PLANTS

Disease resistance and disease susceptibility are as yet imperfectly understood. The cause of the inherent differences in the tendency of this or that variety to suffer, as with the leaf-curl in the Elberta variety of peach, the apple scab predisposition in White Pippin, Winesap and others, may become in practice, varietal weaknesses. Yet such is the commercial superiority of some such varieties that they increase in public favor despite these weaknesses. The great differences among varieties of fruit in susceptibility to the diseases which prevail under certain conditions, is a matter of observation and experience. From the difficulties involved in breeding a less susceptible or more resistant type of tree fruit belonging to any commercial variety, increased resistance is not yet within reach. This applies to established varieties and yet leaves the field open for new sports to be discovered or for its occupation by less desirable sorts which do not suffer so severely from disease. This actually happens in the growing of pears outside of certain favored districts; owing to the ravages of fire blight, a bacterial disease, the ordinary grower selects less popular but more resistant varieties for culture.

In the study of disease susceptibility it has been shown that other features being the same, the percentage of water is an index: thus, parts having the higher water content are attacked more readily than those with lower water content.

With annual plants or those reproduced each year by tubers or seed, the opportunities to breed resistant strains are extremely good and the results obtained are highly promising. Physiological weakness in plants may often be translated in terms of disease susceptibility; this holds with emphasis in vegetables and grains. Apparent physiological vigor may arise from various causes, and when expressed in terms of more rapid growth or higher water content or succulence of the parts may be indeed a source of weakness in the midst of disease. Selections made for the purpose of securing resistance to disease are made under conditions of *disease prevalence* with highest promise. This field of breeding for disease resistance is one of fruitful promise.

Studies in this line have been made by the Horticultural Department of the Station in respect to resistance of potato plants to the early blight disease. By selection of hills that withstood early blight attack and planting tubers therefrom and subsequent repetition of this work (See Bulletin 174) early blight resistant strains were secured. The differences between these strains and non-selected tubers in 1908 during the marked prevalence of early blight was very striking and clearly showed that a tangible resistance capable of reproduction has been secured. Owing to the wide extent of this field with vegetables and grains, much may properly be expected from breeding for disease resistance in the future. Much progress has been made with cotton resistant to wilt and with musk melons resistant to leaf blight. For the present other remedial measures will also need to be pushed.

CONCERNING PARASITIC FUNGI

A fungus (plural, fungi) is a plant, a member of the class called fungi. The fungi are low in the scale of plant life, being classed with the algæ and other similar plant forms. They are lower still in the life scale than the mosses and liverworts; above the mosses come the fern-plants, and above these the seed plants, such as grasses grains, clovers, trees, shrubs, herbs and the like, with which we come in contact every day. The fungi are distinguished from higher plants as well as from their nearer relatives, the algæ, by the absence of green color, and for that reason, we may assume, by the lack of power to prepare their own food from the mineral substances dissolved in water, and from the gases contained in the atmosphere.

Herein they are marked off from most groups of plants: the fungi must live upon the substance of living or dead plants or animals. If they ever possessed the power of utilizing the same foods as most other plants, this ability has been lost. Parasitism is usually taken to indicate degeneracy in character. One way of regarding the fungi is as algæ without chlorophyll, to which the latter owe their green color. As above stated, the fungi are, in the absence of chlorophyll, forced to live upon the dead remains of plants or animals, or to prey upon the living organisms.

CLASSES OF FUNGI

Such fungi as subsist upon living plants or animals are called parasitic fungi. A parasite is one who eats at another's table and the adjective "parasitic" comes from this word, parasite. It is the parasitic fungi especially of which we must learn, since this class produce diseases when they attack other plants. The plant attacked is the "host" plant, however unwilling the entertainment of the sycophant.

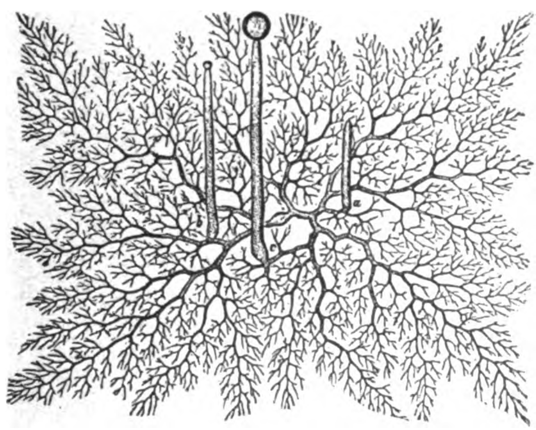


Fig. 6. Mycelium of the common mold (*Mucor Mucedo*). From the spore lying near the middle of the figure, and strongly swollen, one sees the thick threads of the mycelium arise; these in turn become richly branched. There are no divisions in the mycelium. From the level of the mycelium arise three vertical fertile hypae, *a*, *b*, *c*, of which *a* is still very young and that at *b* is already producing a sporangium containing many spores. All highly magnified. (After Zopf, from Reinke).

Most fungi are very minute in size and require the use of a microscope to study their parts; certain ones, however, such as the mold upon bread or other foods, may be seen very easily to consist of fine, thread-like growths interwoven together, and bearing certain rounded parts upon erect branches. Some idea of fungus-structure may be obtained by studying these common molds; that on a discarded melon rind will shows the parts above described, and by the use of a microscope we may learn that the rounded, ball-like enlargements just mentioned consist chiefly of small bodies that are capable of growing into other fungus-threads. (Fig. 6). Such minute parts capable of germinating and again producing the fungus are called spores. Most spores are very minute and are not heavier

than the other dust particles carried by the wind. The spores of fungi are the means by which these are most commonly reproduced, somewhat after the manner that the higher plants about us are reproduced by their seeds.

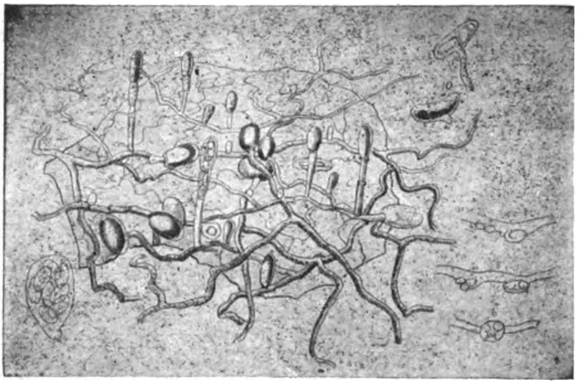


Fig. 7. *7a.* A portion of leaf of pea showing breathing pores and parasitized by powdery mildew; the horizontal threads (*sterile hyphae*) and summer spore bearing parts of the mildew fungus (*fertile hyphae*) are distinctly shown. In these latter the septa are evident. *7 b.* A spore sac (*ascus*) of the same fungus. 4, 5, 6, show the sucking organs (*haustoria*) of the sterile hypae of this fungus; these penetrate the epidermis of the leaf. 10 shows the spores of the rose mildew germinating. All highly magnified. (After Tulasne).

Note—The stomate in foreground is distorted. See Fig. 2.

While we have cited the bread mold as a good illustration to show the structure of a fungus, it is not a parasitic fungus; a mold or like growth which lives upon decaying material is called a saprophytic fungus. To this same belong the mushrooms or toadstools that may be found in manure piles, in the woods and in orchards; the fact that we find them in such places shows that there is decaying organic substance at that point, upon which these plants may subsist. A like condition is found in the shelf-fungi on old logs and stumps, on the under surface of which we may write our names. Yet if we will use a hand lens we may often discover this under surface to be but a network filled with small openings or pores from which the spores of the fungus will in time escape. In like measure the spores of mushrooms are found in similar canals or upon the sides of the gills beneath the cap of this sort of fungus. The bacteria, or fission fungi, are one-celled plants multiplying by division and by spore production; with bacteria evident mycelium is lacking and they are structurally lower in the scale of plant life than fungi provided with a mycelium. Bacteria are both parasitic and saprophytic. But to return to parasitic fungi:

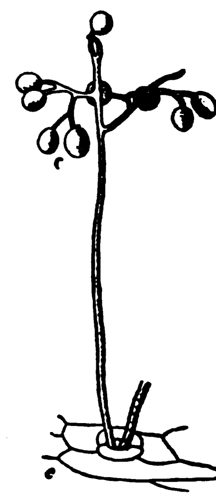


Fig. 8. Fertile hyphae (*conidiophores*) of the downy mildew fungus on *Cardamine*, a mustard protruding from a stomate; the one shown in full, bearing spores at the end of its branches. Highly magnified. Very similar to this are the downy mildews of grape, cucumber, lettuce and some others. (After Zopf).

PARTICULAR FACTS ABOUT PARASITIC FUNGI

Like the bread mold, or the other fungi just mentioned, parasitic **fungi** consist of a growth of threads or hyphae (singular, hypha) **which do** the necessary work of getting food for the parasite; these **also in due** time give out certain branches destined to bear spores, **somewhat** after the manner that the pear tree has flower clusters, **or the wheat** plant forms its dense spike of bloom, both of which are **especially** designed to produce seeds from which wheat plant and **pear tree** may in turn be grown. The essential parts of a parasitic **fungus** are these threads, or hyphae, and the spores produced by **them.** The hyphae of the fungus taken collectively are called the **mycelium**, which consists of threads that produce no spores (sterile **hyphae**) and of those destined for spore production (fertile hyphae. **(Figure** 7). It is to the food getting qualities of the hyphae that the **fungus** owes its continual existence, and they in turn arise from a **spore or** directly by the growth of some fragment of fungus-thread, **as the** Carolina poplar may be grown from a cutting. Yet, while all **parasitic** fungi are made up of these few parts, the differences in **form and** apparent structure among the several groups are very **marked;** differences exist as to the thickness of the hyphae whether **or not** the threads are divided into separate cells by divisions like **those** at the joints of a bamboo rod, as well as in the manner of spore **formation** and in the size, color, form markings and structure of the **spores** themselves. It is almost hopeless to undertake to illustrate **types** of spore production and spore forms, since these are so varied **and may** differ so much at different stages of the development of a **single** given species of fungus, yet we may cite a few examples:

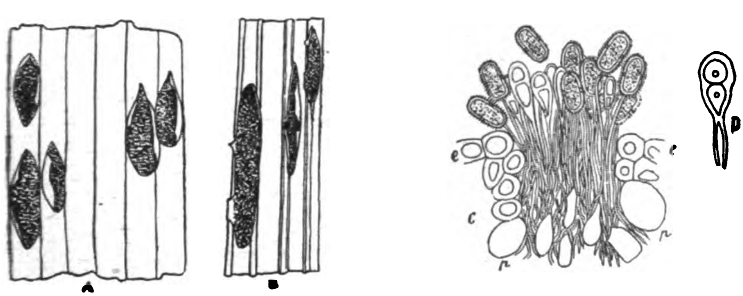


Fig. 9. Showing the common rust of oats and rye. At *A* a small fragment of rye leaf with several orange-red, rust sori breaking through the epidermis; these are of the earlier summar spores (*Uredo*) or red rust of popular speech. At *B* a small fragment of a rye leaf with several black, rust sori, elongated in form, breaking through the external covering; these are of the later summer or winter spores (*Teleutospores*). *A* and *B* slightly magnified. At *C* section through the uredosorus of *A*; on the slender stalks (*basidia*) the rough one-celled uredo spores, and between them a young, two-celled teleutospore, which later alone form the sorus. *e*, *e*, epidermal cells; *p*, *p*, cells of the leaf interior through which runs the mycelium of the fungus. At *D* a teleutospore from the black sorus of *B*; this is divided by a septum into two cells. Similar uredospores are found in most rusts; similar teleutospores occur in corn rust, wheat rust, etc., and in the spores of the cedar apple fungus. *C* and *D* considerably magnified. (After Zopf. [illegible] Frank).

Fungus spores may be produced as single spores or in naked clusters attached to certain branches. We find this sort in the downy mildew of the cucumber and its relative the peronospora of mustards (Fig. 8); in potato early blight; in fruit rot of plum, cherry, peach, etc., and later in the spores of apple scab. They may also be found in dense clusters breaking through the skin of the plant like the many tubers of a potato breaking through the earth-crust; such without further conspicuous covering are found in the rust spots, in the anthracnoses and the like. (Figs. 3 and 9). These dense clusters may arise beneath a special covering resembling nothing so much as the traditional beehive, but are usually ejected forcibly from a specially provided opening at the top of the cone or half-ball. (Fig. 10). A yet more interesting class is that in which the spores are packed so many to a sac (usually eight) and a large number of these crowded into a ball-like, hollow spore-case, such as we find in black-knot, strawberry leaf-spot, the powdery mildews and in some other instances. (Fig. 11). There is yet another sort in which the spore sacs are abundant near the surface of the diseased part, as in leaf-curl of the peach, where the maturity of the fungus is shown by the change in color of the affected leaf surfaces. Other gradations will be found as one proceeds in this study.

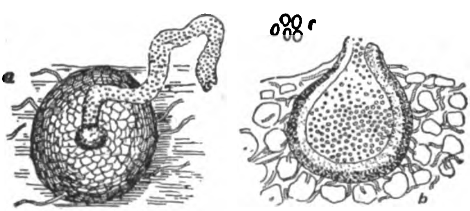


Fig. 10. *c*, spore case (*pycnidium*) of a beet leaf-spot fungus (*Phoma*) seen from above and showing the slender, flexuous mass of spores, ejected from the pycnidium. *b*, section of a pycnidium, seated in the leaf tissues and filled with spores. *c*, a group of the spores. All highly magnified. (After Allescher from Delacroix).

THE SURVIVAL OF PARASITIC FUNGI

Further, respecting parasitic fungi we must realize that they are all derived by specific processes of reproduction peculiar to the fungus in question; in other words spontaneous generation does not find support among the students of plant diseases.

The presence of any given fungus leads us at once to infer the previous existence, somewhere within reach, of a fungus of like species from which this one was derived by definite methods of reproduction. Likewise, the destructive prevalence of a parasitic fungus in any given time and at any given place, assures us of the necessary supply of spores to start the trouble again under favorable conditions. In fact, all our study leads us to look through mere phenomena, mere evidences of disease, to find the specific parasitic growth which causes them and the favoring conditions under which

these develop. The spores of fungi serve for them the same purpose as do the seeds in higher plants; by reason of the extreme smallness of the spores they are easily transported by the wind and become deposited like dust particles upon exposed surfaces. Certain resting spores survive on the fallen leaves or other parts and will be destroyed if these parts are burned. (See black-knot). The survival of organisms capable of infecting the new crop is certainly to be expected in plant diseases as in epidemic disorders among people.

Some fungi which produce disease survive by their thread-like parts (*mycelium*) in a manner similar to the survival of Canada thistle quack-grass and the mints among troublesome weeds by their visible underground stems. A good illustration of this form of survival is found in the case of potato rosette; in this disease the masses of mycelium (*sclerotia*) remain upon the surface of the potato tubers and unless destroyed by treatment of the seed will be ready for immediate attack upon the growing plants (sprouts), even before these have reached the outer air and taken on a green color.

Similar survival may occur in cultivated soils, especially where the same or closely allied crops are grown in succession. Thus the same fungus as that of the potato disease first named, survives in greenhouse soils or in celery soils outdoors.

RESTING FORMS AMONG FUNGI

The active parasitic phases of fungi necessarily coincide with the activity of the host plants; it, therefore, follows in our temperate climates with alternating periods of activity and rest of growth and practical somnolence, that the parasites require to be mutually adapted to intermittent activity. Some spores will survive the brief rest period between harvest and seed time, as in a number of the various grain smuts and in grain anthracnoses. Here they are found simply adherent to the seed grain.

Seed infesting parasites like the loose smut of wheat, the anthracnose of pea and bean, and a variety of other vigorous species survive as resting mycelium, which remains virtually inactive so long as the parasitized seed is not exposed to conditions of moisture and temperature such as bring about germination.

There are endless gradations between these instances of "resting" mycelium and the protected fruit cases of the higher type of fungi. Thus the perithecia or closed fruit bodies of the wheat scab fungus, develop shortly after harvest upon the infected glumes or culms of wheat, and may be observed by the unaided eye, as black bodies seated upon the pink mass of the summer form. These fruit bodies in this case are the kind called "perithecia," which contain

within them spore-sacs of a nearly fixed number and each sac contains a fixed number of spores of definite form for each species. A great many fungi develop these "housed" or protected forms during the dormant period, and indeed, spore development may proceed in the periods of lower temperature.

With the perithecial or sporehouse form of wheat scab, (*Gibberella*), the spore sacs are formed during the later summer, in our latitude, and these spore sacs disappear before midwinter. For each genus or species under study, peculiar time relations of development may be discovered. The perithecial or spore sac (*acsigerous*) form just described, or some comparable development of the spores under a definite cover-form, is viewed as a more or less ultimate stage in the development of the higher fungi—the summit in the cycle of their development.

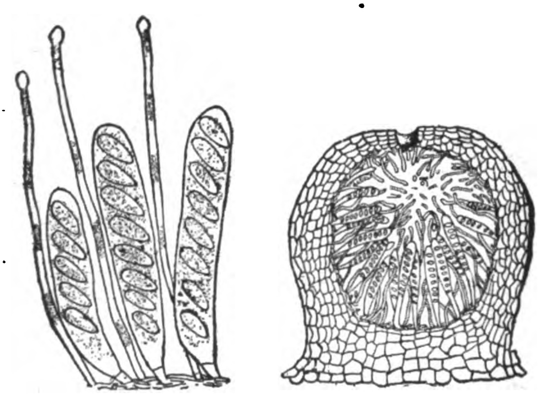


Fig. 11. Section through a spore case (*perithecium*), late winter stage of black-knot fungus, showing spore sacs (*asci*) within. Beside it, three asci containing winter spores or ascospores, eight in each sac, arranged in a definite manner. Along with these are thread-like hyphae known as paraphyses

The rot of stone fruits, such as peach, plum, cherry and the like, is commonly known only in its conidial development called *Botrytis*. Recently Norton has discovered the *Sclerotinia* or ascigerous stage developed from the mummy fruits in which the fungus lay dormant for a time awaiting spring or summer conditions.

The bitter-rot of apple and its cycle of development not long since brought to light in Illinois, also shows the relation of the apple mummies, decayed by attacks of this anthracnose, to its survival. The fungus lives over in the old rotted fruits, acted upon by bitter-rot alone, which hang upon the trees. The fungus may also survive in branch cankers upon the tree adjacent to mummies of the bitter-rot. In these branch cankers the spore sac or perithecial stage of the fungus is developed. Upon the coming of warm showery weather about early June, new spores are produced from either mummies or cankers and new infection may occur upon the new fruits. The problem of the control of this disease, therefore involves a knowledge of its manner of survival.

ALTERNATION OF HOSTS IN FUNGUS SURVIVAL

This relation of alternating forms in the life cycle of a given parasitic species, to its survival, has been mentioned in wheat scab wherein we have the *Fusarium* or pink mold and the *Gibberella* forms; in rot of stone fruit where we find *Botrytis* and *Sclerotinia* forms, and in apple anthracnose or bitter-rot where we discover the *Gloeosporium* followed by the *Glomorella* ascospores. In these instances there seems no real need for the advent of *another host plant.* In other groups of fungi, notably among the *Uredineæ* or rusts, we discover in certain species, that survival is accompanied by a necessary change of host plant. The apple rust is known in summer to attack the leaves and fruit of apple, thorn apple (*Crataegus*), june-berry and mountain ash. This is the aecidial or cluster-cup stage of the apple rust and has its counterpart in the aecidiospores or cluster-cups of the wheat rust upon barberry as well. With apple rust we climb far on the plant ladder and find the teleutospores of rust survive upon the cedar trees as branch enlargements called cedar apples (*Gymnosporangium*). The dry looking apples upon the cedar trees take on a new form during spring showers when they become great, jelly-like masses which emit the teleutospores of the rust, to be carried to apple, juneberry and crataegus leaves by whatever agency is available.

The relation of cedar trees to the prevalence of apple rust is a practical matter for each orchardist. It may be better to make firewood of the cedar trees than to combat the apple rust in his orchards. A similar problem as between the barberry hedges which adorn rural England, and the virulence of wheat rust in their grain fields, may also be raised. With us we have plenty of grain rust in the absence of barberry hedges. An adaptive form of survival apparently takes the place of the alternating hosts, and we still have the wheat rust.

The instances given are simply illustrative and the student of plant pathology will discover many more in the course of his study. Likewise a careful perusal of the special part of this bulletin will show other instances of survival under many various and instructive conditions.

HOW THESE PARASITES ROB THE HOSTS

There is an old saying about the stable door and the stolen horse; similar application may be made for plants and parasitic fungi in a manner which we shall presently perceive. To obtain food we must reach the source of supply; the manner of reaching it is less important than the result. Now it occurs that cultivated and wild

plants of the higher classes are wrapped about by a covering of skin or bark, and the food-filled juices are within; to feed upon any living host the parasite must gain access to the internal tissues of that host. It so happens that there are minute openings or stomates (breathing pores) through the skin of leaves and of young green stems; these openings are as necessary as the stable door, and through them the thief may enter. (See Fig 4). Were these openings to become entirely closed the plant would languish, and remaining open, they constantly offer a way for the tender tip of the growing germ thread of a fungus to push its way through the plant covering and to luxuriate within the host upon the substance of the plant. Once within, the fungus thrives, rapidly multiplies its branches, and if in summer, commonly thrusts its fertile threads through some of these breathing pores to bear its spores outside where they may become more widely distributed than if remaining within the tissues of the host plant. Should, however, the winter season be near, resting spores may be formed, or their formation be provided for within the leaves, or diseased parts, as in grape downy mildew, elm-leaf disease and in black-knot of plum and cherry. Thus the cycle of development continues indefinitely unless some agency intervene to destroy the spores, to prevent their germination, or the parasite itself so exhaust the host plant as to destroy it entirely and the fungus perish for lack of suitable nidus. However, this rarely occurs, not perhaps, so often as men are guilty of killing the goose which lays the golden egg. Herein, we meet another fact, namely, that parasitic fungi of a given kind are limited to a particular host plant of a certain species, or to a small number of related plants, so that if a congenial host is lacking the fungus will not thrive.

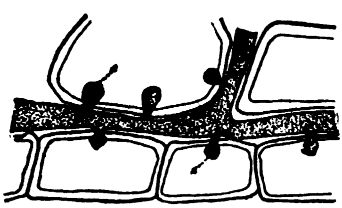


Fig. 12. Haustoria of the fungus of the grape downy mildew penetrating cells of grape stem. The shaded portion shows the mycelium of the fungus growing between the cells, sending haustoria, *a a*, into the interior of the cells. (After Scribner from Farlow).

Note: In this figure the lower row of cells have the form of empty epidermal cells in which the fungus would find little to subsist upon. Farlow's original figure does not give these cells such form.

The fungus threads growing within any plant will not flourish if simply passing between the cells of the host; penetrating organs pierce the cell walls and are able to absorb nutriment from the cell interior. (Fig. 12). The diverse forms of sucking organs, and the peculiar structures of fungus threads in these situations would in themselves require much study and investigation to present them properly. We must further conceive that a fungus may often

penetrate the bark of a tree for example, if aided by rifts caused by freezing or similar disturbances, to say nothing of the openings offered by wounds, the breaking of branches, etc. A recent illustration of the danger of rifts in the bark of trees is offered by the chestnut disease which is proving so destructive near New York City. Few parasitic fungi have that penetrating power of thrusting the haustoria through the plant covering such as we find in the case of the dodder that twines about and robs the wild herbs and shrubs of the woods and fields as well as the cultivated flax and clovers.

HOW PARASITIC FUNGI AFFECT THE HOST

We know the cumulative effects of insufficient food supply; these effects must hold for plants attacked by parasitic fungi. Aside from the nutriment diverted to the parasite, there is reduced functional vigor of leaf, stem or root, and the loss becomes increased in this way. Let all the leaves be parasitized, or let even three-fourths of them be entirely so attacked, and we may look for great loss of foliage, possibly entire loss of fruit and the detailed effects of diminished vigor, unripened wood, or by repetition, entire destruction of the host. Usually the effects are of many gradations, but in all cases of leaf parasites the entire plant must suffer. We have learned that bacteria may, in a suitable medium, destroy themselves by the formation or emission of poisonous products which are fatal alike to the bacteria and to animals, or even man; that such takes place within plants parasitized by fungi remains in doubt, and may be disregarded for the present. The results of impaired function in the parts are serious enough to demand our attention. It is altogether probable that future investigations will modify our views upon some points.

There are many curious transformations and malformations resulting from the attacks of parasitic fungi, simply by the multiplication of cells of wound cork or other tissues in the effort of the host to shut off the fungus, not because the fungus consists of such a mass of tissues. (See leaf-curl of peach).

While exceedingly interesting to trace the effects of the white mold on shepherd's purse and on the garden purslane, as well as the effects of bramble rust, cabbage club-root and a number of others, the principle above pointed out will be found generally applicable, and it is to the reactions of the host plant that the excrescences or malformations are chiefly attributable.

It may further be stated that artificial cultures of parasitic fungi, either upon culture media or living plants are constantly adding to our knowledge in these lines.

BENEFICIAL ORGANISMS: ROOT NODULES, ETC.

While realizing the losses caused by parasitic fungi and bacteria we may not hastily condemn all fungi and bacteria. One of the most profound influences of aging culture of the soil is the beneficial

effects in nitrogen fixing, exerted by the root nodule bacteria of leguminous plants. The well known beneficial effects of the root nodule bacterium upon clover has made rotation in clover an agricultural necessity. The species or forms of root nodule bacteria required on alfalfa, cowpeas, vetches, etc., have become recognized as factors of consequence in our efforts at seeding and new species of legumes on the farm.

A less understood relation between certain fungi which develop as mycorrhiza upon the roots of some deciduous trees and notably on conifers may not be passed. Herein we may find an explanation of rotation in forest species when reforestation crops are to be grown.

THE PROOF OF PARASITIC CAUSE IN PLANT DISEASE

The mere presence of a fungus, determined by the microscope in diseased tissues of the plant, does not prove the case against the organism found. It is not easy at all times to be certain whether discovered spores belong to this or that organism, or group of organisms, although with certain groups as the anthracnoses, species of Fusarium, etc, the spore forms give somewhat clear evidence. The differences between parasitic and saprophytic fungi are not always simple matters admitting of ready determination; further, we must bear in mind that after a parasite has caused death or even minor lesions in a plant, the organisms of decay may be expected to appear to do their great work as the scavengers of the world. The fungi or bacteria found in a dying plant may be both saprophytic and parasitic, or these may be only saprophytic.

The methods of proof of parasitic cause in the bacterial diseases of animals including man have been extended to the study of bacterial diseases of plants and finally to the diseases caused by parasitic fungi. These methods consist of a group of rigorous exact rules which are stated by Dr. E. F. Smith in the following terms:

(a) Constant association of the organism with the disease.

(b) Isolation of the organism from the diseased tissues and careful study of the same in pure cultures on various media.

(c) Production of the characteristic signs and lesions of the disease by inoculations from pure cultures into healthy plants.

(d) Discovery of the organism in the inoculated, diseased plants, re-isolation of the same, and growth on various media until it is determined beyond doubt that the bacteria in question are identical with the organism which was inoculated.

Smith—Bacteria in Relation to Plant Diseases. Vol. 1, p. 9.

While these methods and rules are stated with special reference to bacteria as the cause of disease, they apply with equal force to the proof of cause in the case of any given parasitic fungus. These methods require rigorous and exact work in the isolation and subsequent culture of the parasite upon sterile media, followed by equally careful inoculation work using these pure cultures as a source of the organism.

METHOD OF INOCULATION FROM CULTURES

The methods of inoculation tried by the investigator are of great importance. These determine, in fact, the success or non-success of his efforts. There must be adaptation of the method to the life history of the parasite and the developmental stages of the host plant, including the appearance of the parts more commonly attacked by it.

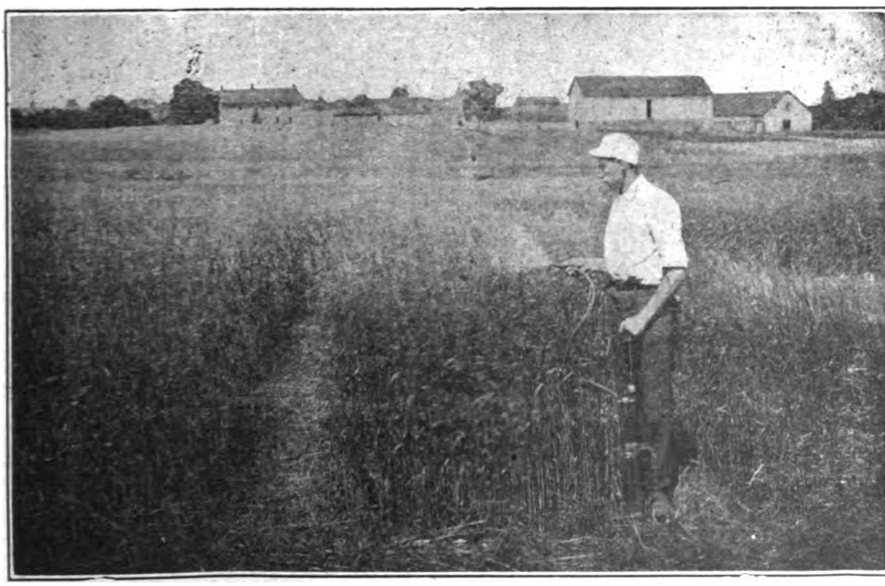


Fig. [illegible]. This shows method of infecting field plots by means of the hand spray pump, using the washings of samples of wheat and other grains. The washing of grain containing spores of disease such as anthracnose or scab may be used. Cultures may also be sprayed upon plants in this way or by means of blow-bottle in smaller tests. (From Bul. 203, Ohio Experiment Station).

Following the methods of earlier bacteriologists, needle pricks are often employed both in the inoculation of fungi and bacteria into plants. One seeking to pursue a special line of inoculations will need in all cases to study his conditions as well as the methods of other investigators. Thus, doubtless, inoculations like those of Phytophthora and Plasmopara may be best attained by using drops of sterile water to carry the spores. The same principle applies in field

methods upon many crops. In the case of grain diseases, notably anthracnose and scab upon wheat, rye, oats and grasses, inoculations may be made by spraying the cultures upon the grain at a proper stage of its development.

While some groups of fungi do not lend themselves readily to culture upon the usual media, it is the aim of plant pathology to make this possible with a constantly increasing number of these parasites.

CULTURE PROOF NOT ALWAYS POSSIBLE

While in all cases of bacterial diseases where the body of the organism is so little different from that of the bacteria of decay, fermentation, etc., these rigorous proofs are required before the disease is listed as of proven bacterial origin, we do not find it necessary in practice to reprove again the case as against frequently occurring species of fungi associated with particular plant diseases. This does not make it less necessary to prove all cases as to parasitic cause, although the practicability in any single laboratory of pathology is admittedly one of narrow limits.

ENZYMATIC DISEASES OF PLANTS: CHLOROSIS OR PANACHURE

To this form of physiological breakdown, induced however, by specific causes recently determined, we attribute some very widespread and injurious diseases which belong under the head of chlorosis. Peach yellows, possibly peach rosette, frenching or mosaic disease in tobacco, and in general variegated or special yellow foliage types of plants as in Arundo, Acer and other genera of plants belong here. The yellows in peach has long been studied, as also the tobacco mosaic disease. In yellows the contagious character of the disease and its transmission in pruning by contact of parts of the harness of team and by or through the atmosphere has been recorded.

A few years ago it was determined by Beierjink and by Hunger that this infection exists as a chemical compound or compounds of complex nature belonging to the oxidizing ferments of a group called the oxidases. Oxidase, peroxidase and others of these ferments are known. They act by breaking down or oxidizing the plant leaf tissues and especially the chlorophyll or leaf-green of foliage and young tissues, converting it into xanthophyll. The tests for these ferments are of some importance. Woods and others have shown their action with peroxid of hydrogen.

From a practical point of view the transmission of the ferments, and, therefore, of the disease, by touching first diseased and then healthy foliage is rather surprising. The work of Hunger in Java

upon the transmission of the tobacco mosaic disease makes the risk of transmission from diseased to healthy plants by such handling, stand out clearly. This line of transmission was verified on tobacco by the writer's assistant in 1903 (See Bulletin 156, of this Station).

While the same class of proof for peach yellows is very difficult, owing to the latent nature of the disease for some months after first infection, the actual results of infection from nearby diseased trees make clear the danger of such exposure and the necessity for the destruction of diseased trees. Chemical examination of variegated or chlorose tissues shows the same compounds, the oxidases, etc., to be present and to account for the transformation of the leaf-green or chlorophyll, into xanthophyll, or leaf yellow. Thus by degrees apparent plant disease mysteries are solved. The weakness of variegated plants and their ready susceptibiity to attacks of parasitic fungi are now explained by this impaired condition of the leaf parts.

PLANT DISEASES TRANSMITTED IN THE SEED

The public in general little realizes how many diseases of plants are transmitted in the seed, although as the years pass the general dissemination of knowledge concerning infection by spores and by germs has partly prepared the way. The public mind does not longer expect something to grow from nothing. The treatment of seed grain, as wheat, oats, barley, etc., to destroy adhering spores of the smut fungi, and thus prevent these smuts in the crop, has been known for many years. In the early days of the Agricultural Experiment Stations, these doctrines and practices in this regard were widely disseminated, new impetus being given by the successful use of hot water following the methods of Jensen in Denmark; but despite the conquest of the practical control over the order Ustiligineae, the smuts, we have only really begun to study the matter of seed infecting diseases produced by seed infesting fungi. These seed infesting fungi are of two types, viz, first, those whose spores adhere to the seed grain as in the case of the smuts of grains generally, and second, and more exactly, those fungi which develop upon or within the seed largely by their threads or mycelium, and may, or may not, prevent the germination of the infested seed grain. Our knowledge of these strictly seed infesting fungi is quite recent; we may point to the work of Prof. Bolley and his assistants at the North Dakota Experiment Station, especially upon the matter of flax diseases; to the work of Dr. Halsted in New Jersey and to Bulletin 173 of this Station by Van Hook. With the tendency to continuous growing of flax, in the west there was developed a

that new area specific seed and soil troubles which have been proved to be perpetuated in the infected seed. An anthracnose of flax and a Fusarium attacking flax seed are examples.

No less conspicuous is the case of the blight fungus of peas, *Ascochyti pisi*, which is also an anthracnose, and the allied anthracnose of beans, *Colletotrichum lagenarium*. Investigations made at this Station by Van Hook show the source of the trouble with peas to be the infected seed employed and show also that seed treatment will not destroy these internal fungi without destroying the vitality of the seed. It was further shown that the source of relief lies in growing healthy seed through the use of fungicides upon the pea vines from which seed is gathered; likewise that infection may remain in the soil, (See Bulletin 173).

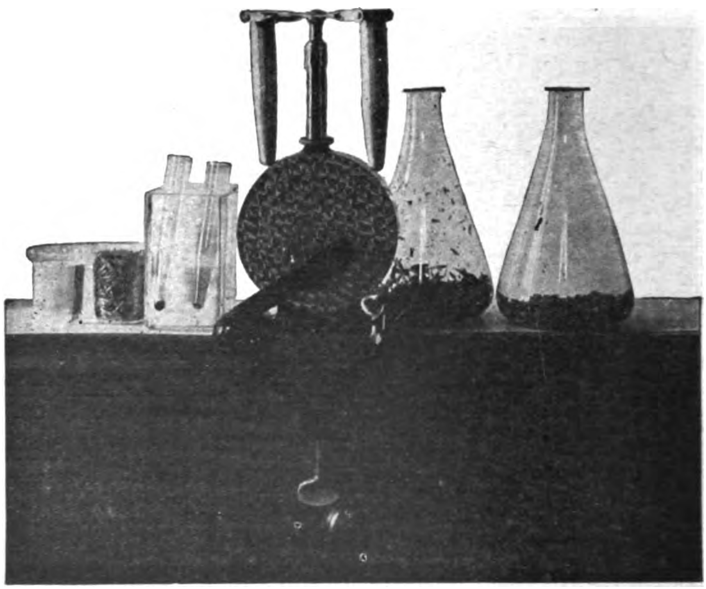


Fig. 14. Showing physician's centrifuge and other apparatus used in making examinations of grain washings for smut spores and spores of other diseases adhering to the exterior of seed. The flasks at the right show samples of washed grain. Those at the left show amounts of grain and water used. The glass tubes in container are used in the metal holders of the centrifuge. The precipitates in bottoms of tubes were obtained from washing of oats and wheat samples in flasks. (From Bul. 203).

More recent work at this Station has shown the presence of seed infesting and seed infecting diseases in wheat. (See Bulletin 203). The illustration, Fig. 15, exhibits the germinating seeds of wheat with the outgrowth of the parasitic fungus (*Fusarium*) which we find associated with wheat scab. This is upon seed grains (kernels) that are not destroyed by the fungus; many of the kernels of scabby

heads will not germinate. It was also found in continuous wheat land as much as 6 percent of the young wheat plants were destroyed in the fall by this same parasite which appears to survive in the soil under continuous wheat growing as well as to be propagated in the seed grain.

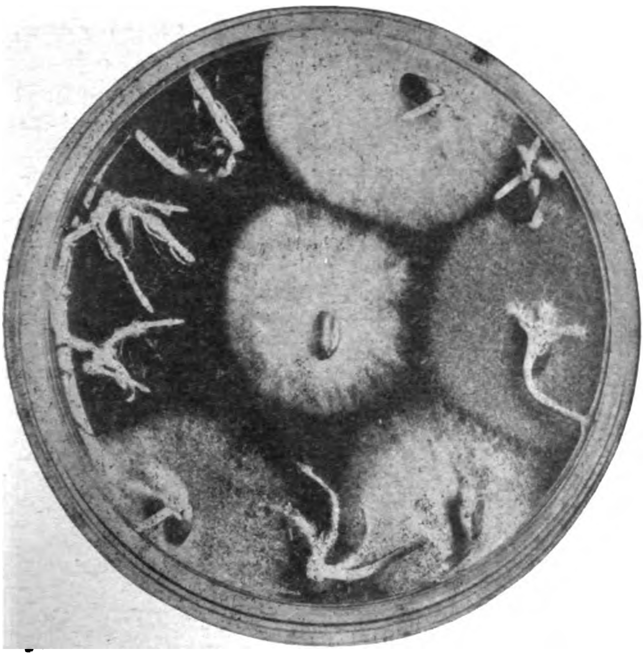
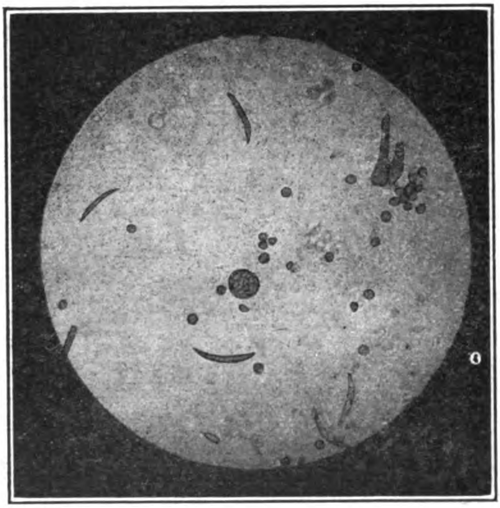


Fig. 15. This shows results from germinating ten wheat kernels in Petri dish containing agar. Both the agar and the kernels were sterilized. After five days it was found that five kernels had produced healthy plantlets, and four kernels had germinated but were attacked by the scab fungus, *Fusarium*, and two by another fungus. One kernel in the center did not grow and gave only growth of the scab fungus, *Fusarium*. (From Bul. 203).

HOW TO EXAMINE SEEDS FOR INFECTION

Recently good success has been obtained in the laboratory of this Department in determining the presence of certain seed infesting fungi in seed wheat, oats, rye, etc. In regard to the matter of adhering spores this is accomplished by making washings of the seed in distilled water and separating the spores from the washings by means of a physician's centrifuge. (Fig. 14). The spores and similar particles washed from the seeds are thus collected in the bottom of the tubes of the centrifuge and may be identified by microscopic examination. (Fig. 16).

Examples may be multiplied to illustrate the range of seed infection both by adhering spores and by internal development of the mycelium of the invading fungus. Many of these are treated under the particular diseases of the crops. The bean, pea, barley, broom-corn, flax, millet, potato, sorghum, rye, sweet-potato, and wheat will all furnish examples. Not only have we to test the actual survival of the parasites thus found but we must discover the behavior of the disease with respect to the germination and seedling plants which grow from such infected seeds or tubers. Examination for infection of seed bulbs and tubers may be made either with or without the growth of plants from them. With potato scab and rosette, the external scab effects or the sclerotia of *Rhizoctonia* are not difficult to see. With the latter the moistened tubers show marked color contrasts and make the work easier. These diseases are reached by seed treatment.



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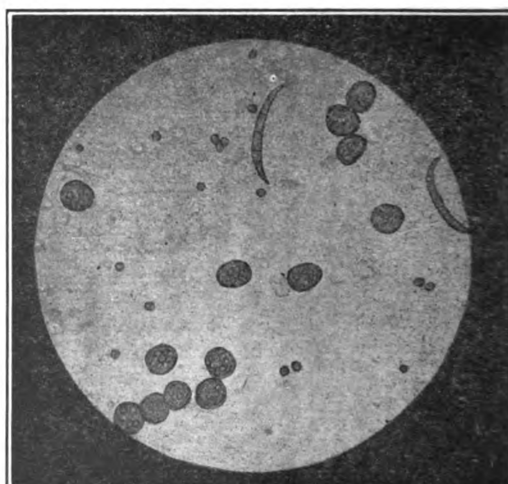

b

Fig. 16. Microscopic photographs from centrifuge precipitates of wheat washings. *a*, from wheat washings, narrow, slightly curved anthracnose spores, small spherical, loose smut spores, large spore of stinking smut and portions of the setae of anthracnose. *b*, from wheat washings, small, loose smut spores, large stinking smut spores and curved scab spores. All magnified about 180 times.

Where the infection is internal by the threads or mycelium of the fungus, the seeds may be germinated in Petri dishes where the kernels are surrounded by a moisture retaining, sterile medium

such as agar or gelatin. This method has been worked out in Bulletin 203 and may often be applicable. The illustrations above will show the results in these cases as before referred to. With internal tuber infesting diseases as in the bacterial wilt disease of the potato, the Fusarium wilt or dry-rot fungus of the potato and the soil-rot of the sweet potato, we must go further than mere external examination. For the two named wilt diseases of potato, infection usually shows earliest at the stem end. Thin slices across this stem end of the tubers will show whether or not there is discoloration in the vessels. In the absence of infection there will be no discoloration with bacterial infection by *Bacillus solanacearum*, black areas or rings will be seen in these tissues while tubers infected with *Fusarium oxysporum* will show local areas of browned or blackened tissues. This infection applies usually to harvest time. As the infection advances, one-half the length of the tuber or even more may become infected. In all cases sections from sterilized tubers may be used as a source of cultures in Petri dishes. The same applies to soil rot of sweet potato. These diseases are not reached by seed treatment.

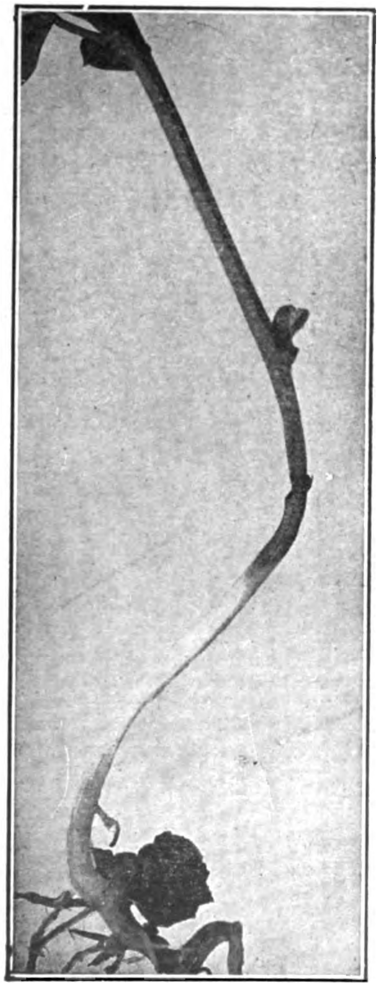

Fig. 17. Pea stem showing lesion from blight fungus, *Ascochyta pisi*, near surface of ground. This fungus came from the seed pea. (Natural size). From Bul. 173.

THE LIMITS IN SEED TREATMENT

It will be apparent that serious limits hold in regard to seed treatments. Where the spores are external and simply adhering to the seed grain, treatment will destroy these spores if rightly adapted to the seed in question and the germination need not be much, if any impaired. On the other hand where the seed infection is internal rather than external, grave doubts arise as to the possibility of successful seed treatment.

It has not been found possible in the cases of seed peas when inte
with the blight fungus, or of seed wheat, rye, etc.,infected wit
scab and other fungi to apply any seed treatment which w
destroy the infecting fungus without destroying the vitality o
seed grain. In general we may say that where the seed infecti
fungus spores, etc., are external to the visible or germinable g
seed disinfection through treatment is possible, but for the int
fungi it is rarely possible. The loose smut of wheat may be a
able to special seed treatment with only partial loss of vitali
the seed wheat.

Fig. 18. Potato tubers attacked by Dry Rot Fusarium, showing sections near the stem-
infected potato tubers. This infection may be easily discovered by cross sections made with a
knife, and sections from sterilized tubers gives cultures in Petri dishes. At times the discolo
extend to the middle of the tuber. (From a photograph by T. F. Manns).

METHODS OF SEED TREATMENT

The methods of seed treatment heretofore employed are
forth in the spray calendar and consist in an immersion of the
in hot water of definite temperatures or in solutions of formaldeh
of different strengths. The formaldehyde solutions may als
employed to sprinkle piles of seed grain and in this manner
handling of the grain is required. More recently it has been
posed to disinfect seed potatoes, onions, forage, etc., through f
gation with formaldehyde gas liberated by boiling the solution
better by mixing formaldehyde or formalin solutions with pul
ized potassium permanganate by which the gas is liberated.

With seeds, tubers, roots, bulbs, etc., the limitations of
treatment are not so narrow and these may be immersed for lon
or shorter periods in solutions of corrosive sublimate, forma
hyde, etc., or they may be exposed to fumigation with gase
formaldehyde as has just been stated. (See Seed and Soil Tr
ment, pages 344 and 345 following.

SOIL INFESTING PARASITES IN FIELD AND FORCING HOUSE

The cultivated soil is a medium in which many species of bacteria and fungi survive from year to year. The public is familiar with the doctrine of bacterial infection or inoculation of the soil in its relation to the nodules or tubercles of clover, alfalfa, soy beans, cowpeas and other cultivated plants of the Family of *Leguminosae*. One form of bacterium is not sufficient for both clover and alfalfa. This flora of the soil both in relation to bacteria and fungi of considerable range of species, is enriched by the applications of manure and by the practices of culture; by this is meant that the growing of a given crop a second time or a third time consecutively in the soil increases the probability that the plant roots remaining in the soil are carried over from one crop to the next together with root parasites which cause disease in the plants of this crop. Manifestly, likewise, if in preparation for a given crop to be grown for the first time upon the land, rather liberal applications are made of fresh stable manure containing spores or mycelium, more especially the resting forms of mycelium called sclerotia, the soil will become infected by this manurial application. While this source of infection is rather rare in field culture we have specific examples as in the scab disease of potatoes transmitted in this way; the scab of sugar beets may be carried in like manner. But in forcinghouse culture where heavy applications of manure are made, the chances are greatly increased that soil infecion will be produced from the manure.

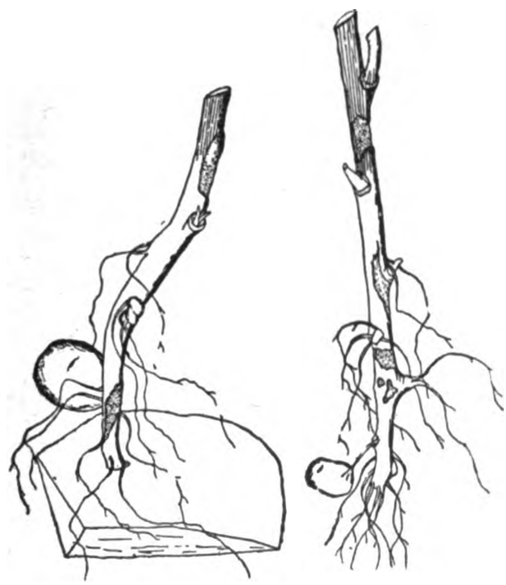

Fig. 19. Bases of potato stems (Carman No. 3) collected June 7, 1902, Cheshire Ohio, showing injuries by Rhizoctonia. The shaded areas are darker lesions occupied by an abundence of Rhizoctonia hyphae; the tops showed conspicuous Rosette effects. Reduced from Bulletin No. 139.

It is of value to remember that seed infesting or seed infecting organisms are also very largely capable of survival in the soil nidus of cultivated soils, thus our troubles multiply adequately if our care be inadequate to avoid them.

Fig. 20. This shows root portions of seedling lettuce plants with dark spots, lesions, caused by attacks of the rosette fungus, *Rhizoctonia*. With the younger plants these attacks cause large mortality and in very small seedlings the stem of plantlet may early collapse after the manner shown in rotting specimens. (From Circular No. 57).

THE AVOIDANCE AND PREVENTION OF SOIL INFESTING DISEASES

We, perhaps, may assert that the law of nature is that of a diversified plant covering; at any rate the law of successful culture will permit of statement in terms of crop rotation. And it is true that as culture ages the number and seriousness of plant diseases increase almost in geometric ratio. It is further conspicuously true with respect to those areas devoted largely to continuous culture in a single crop or in a group of closely related crops such as the growing of wheat in Western United States and Canada, also in the growing of flax and other crops. Potato growing in San Joaquin county, California, illustrates this danger. Muck lands devoted to vegetable culture, tempt the grower to continue his crops of celery, onions, etc. Here we have as a true result the accumulation of diseases which attack these plants; thus for field culture we are constantly facing these problems ot soil infesting diseases and the handling of the diseases is not an easy problem since change to rotation may mean

a serious decrease in the return from the crop on the special type of soil. While for general field culture avoidance of conditions may be successful, this is by no means a simple matter. Rotation is often absolutely necessary, but this same rotation will not rid the soil of the onion smut fungus, nor of some other parasites such as in the case of the club-root fungus of cabbage and related plants. In these cases some soil treatment must be applied to field areas. In the case of the onion smut it is sufficient to apply a formalin drip which will fall with the seed and disinfect the soil layer in proximity to the seed. This is effective because the smut fungus can penetrate the germinating onion plant only in the earlier stages of growth. On the other hand with cabbage club-root, where plants are transplanted from the beds in which they are grown, some general method of soil treatment which involves the soil mass is more effective. In this case it is the application of stone lime or caustic lime in liberal quantities. These examples are only illustrative of general conditions to be met with. In the case of potato scab, it is found necessary both to disinfect the seed where scab is present, even to a limited extent, and to plant upon new soil not infested with the scab organism. Potato rosette is certainly an acid loving parasite.

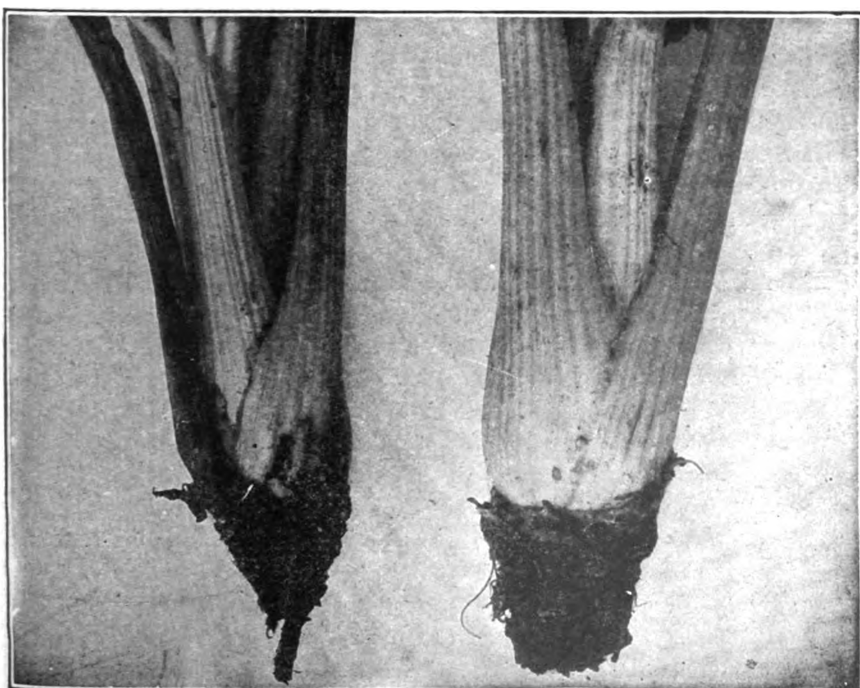

FIG. 21. Lower portion of two c[illegible] plants showing effects of root rot, *Rhizoctonia*. It will be observed that nearly all the roots of the plants have rotted off in consequence of the attack. (From Circular No. 72).

Under the diseases described for each plant, methods of avoidance and treatment are indicated and the diligent student will find other instances of similar character mentioned therein.

SOIL TREATMENT IN THE FORCING HOUSE

About our great centers of population have grown up conspicuous developments of the forcing house industry; large areas are covered with glass and these hothouses are maintained at the necessary temperatures for the production of the special green crops found profitable, At the same time the soil of the hothouse beds is very liberally manured and enriched further by applications of commercial fertilizers. Not only do these applications of manure tend to enrich the flora of the soil and to introduce particular root parasites, but the decay of the organic matter of the manure also tends to produce humus acids in considerable quantities. Along with these are brought parasitic eelworms which are peculiarly fatal to curcurbitaceous plants, to violets and to some other hothouse crops. Next to the eelworms the most conspicuous organism in our area is the sterile fungus Rhizoctonia, whose resting forms or sclerotia may be readily introduced in manure. To meet this indoor soil infection, special methods of soil sterilization had to be developed, since soil rotation is practically impossible in the forcing house.

These methods of treatment are in brief, steaming of the soil to render it practically sterile, so far as these parasites are concerned, and a method of formalin drenching. This method of steaming is ideal, or almost so, in its results upon sandy or loamy soils, but often entails unfavorable changes in heavy silty or clay soils. Essentially, it consists in burying a series of perforated pipes in the soil at intervals, covering the surface of the beds and passing live steam in sufficient volume into the pipes. These pipes are prepared in sets with cross heads and boiler connections and are perforated at desired distances. The surface of the bed is covered with canvas and the steam passed into the system for such period as is required to heat the soil to a temperature from 180° to 212° Fahr., to be maintained for one hour or more. This applies to high pressure boilers; for low pressure or hot water heating systems where the steam is applied in subdrains, four to five hours steaming will be required with a pressure of six to seven pounds. This treatment is effective for destruction of the eelworms or nematodes of cucumbers, violets and lettuce, the rot or drop fungus of lettuce, the rosette fungus, and in general of all soil infesting parasites.

Another method, the formaldehyde or formalin drench, has proved successful for the control of *Rhizoctonia* in greenhouse soils. This consists in a solution of 40 percent formaldehyde in water, say at the rate of two to four pounds in 50 gallons of water. This is applied at the rate of one gallon per square foot of area and will involve a very severe wetting down of the bed and prevent immediate resetting of the soil owing to the persistence of the formaldehyde. One secondary effect of formaldehyde drench and lime in sandy soils in the forcing house was an increased yield of lettuce amounting from 60 to 90 percent over the ordinary crop. This was explained on the assumption that the parasitic fungus was destroyed and certain other inhibiting organisms at the same time.

THE BEST FORCING HOUSE PRACTICE

The best forcing house practice will contemplate a recurrent disinfection or sterilization of the soil during the idle period; it should be preceded by whatever applications of limestone and manure that are to be made to the soil, then after thorough working and application of water to correct unevenness of moisture the soil may be sterilized by steam, or the formaldehyde drench be applied with assurance of results: obviously also this treatment must extend most vigorously to the plant beds and bring healthy seedlings to soil in which the soil parasites have been destroyed.

The following tables of seed and soil treatments taken from the spray calendar will be of more use than extended description or discussion:

SEED AND SOIL TREATMENTS

SEED OR PLANT	FOR WHAT TREATED	TREATMENT	METHOD OF TREATMENT
Barley	Smuts	Formaldehyde or modified hot water	Sprinkling with stronger formaldehyde as for oats is successful. Soak seed enclosed in sacks four hours in cold water, let stand wet four hours more and dip five minutes in hot water at 130 degrees Fahr., or three degrees lower than for other hot water treatments.
Bean	Anthracnose	(See spray calendar)	
	Weevil	Bisulfid of carbon	Submit to fumes for twenty-four hours in air-tight vessel or chamber.
Begonia	Nematodes	Sterilize soil with steam	Disinfect soil to be used by heating with steam as described under cucumbers.
Cabbage and Cauliflower	Club-root	Quicklime on soil	Apply stone lime (quicklime) preferably ground lime, before planting, at rate of 80 bushels per acre and work into the soil with suitable tools.
	Maggot	Bisulfid of carbon or tobacco dust	Make hole in soil near root, pour in about a teaspoonful of bisulfid of carbon and fill holes with soil. Cover soil around stalks freely with tobacco dust once per week.
	Nematodes in hothouse	Sterilize soil with steam	See next.
Cucumber	Nematodes in hothouse	Sterilize soil with steam	Sterilize soil with steam by perforated pipes, high pressure, 1 to 2 hours, or low pressure in subdrains 4 to 5 hours.
	Root-rot	Drench soil with formaldehyde or sterilize as above	Drench soil with formaldehyde 3 to 4 lbs. to 50 gallons of water preceding lettuce crop.
Lettuce	Rosette	Sterilize soil with steam or drench with formaldehyde	Steam as above or drench with formaldehyde 1¼ to 2 lbs. where trouble follows with cucumbers use 3 to 4 lbs. to 50 gals. of water, 1 gal. solution to each sq. ft. of surface. Two weeks must elapse before setting plants.
	Rot	Steam soil	
Oats	Anthracnose	Formaldehyde	Treat seed as stated in next to kill adhering spores. This is only a partial remedy.
	Loose smut	Sprinkle seed with formaldehyde or immerse seed in hot water. Soak seed in potas. sulfid	Preferably sprinkle a pile of seed with shoveling to saturate with formaldehyde solution, one gallon to bushel, at three or four sprinklings; after three or four hours or over night in the pile, spread to dry. Immerse seed contained in open vessel for ten minutes in hot water at 132-3 degrees Fahr., for seven minutes at 136 degrees Fahr., or for five minutes at 140-2 degrees Fahr., spread at once to dry. Soak seed in ¾ percent solution potassium sulfid for 24 hours with stirring, then dry.
	Insects in stored grain	(See wheat)	
Onion	Smudge	Use formaldehyde as for onion smut	Sow seed with formaldehyde as for onion smut; rotate onions with other crops.
	Smut	Use formaldehyde or ground quicklime. Plant other crop. Use sets or transplanted seedlings.	Use formaldehyde solution 1 lb. to 30 gals. of water sprinkled on seed in contact with soil and cover at once, or better sow with drill and drip attachment, the solution falling with the seed. Or apply ground quicklime at the rate of seventy-five to one hundred and twenty-five bushels per acre just previous to seeding on freshly plowed land, and stir into soil. (See Bulletin 131).

SEED AND SOIL TREATMENTS Concluded

SEED OR PLANT	FOR WHAT TREATED	TREATMENT	METHOD OF TREATMENT
Onion	Storage-rots	Disinfect with formaldehyde gas	Fumigate to disinfect the dry onions, with formaldehyde gas in enclosed piles of slat crates for a period of 24 to 48 hours. (See description of method under fungicides).
Pea	Anthracnose (Blight)	Spray the growing crop with Bordeaux	Keep down infection of seed through spraying of plants. See Spray Calendar.
Potato	Scab	Soak uncut seed in formaldehyde or corrosive sublimate	Soak seed for two hours in formaldehyde or one hour in corrosive sublimate; then dry and plant on scab-free soil; formaldehyde gas may be used.
	Rosette (Rhizoctonia)	Soak seed in formaldehyde as for scab	Soak seed in formaldehyde as for scab; on infected soil use formaldehyde after manner in onion smut. (See Bulletin 145).
Roses	Nematodes in hothouse	Sterilize soil with steam	Heat soil with steam as described above; thoroughly disintegrated soil from sod one year or more old is less dangerous. Lime water stimulates affected plants but is not a remedy.
Rye	Anthracnose	Formaldehyde	Treat seed as for oats and wheat to kill spores. Remedy only partial.
Sweet Potato	Black-rot and Stem-rot	Formaldehyde	Soak or fumigate seed roots as for potato scab; discard old diseased hotbeds; drench slightly diseased beds with formaldehyde as for lettuce and tobacco. Then set plants on new soil.
Tobacco	Root-rot and Bed-rot	Drench beds with formaldehyde or sterilize with steam	Drench beds in fall or early spring with formaldehyde 2 lbs. or more to 50 gals. water, 1 gal. to each sq. ft. Do not seed until smell of formaldehyde has disappeared.
Tomato	Nematodes in hothouse	Sterilize soil with steam	As for roses and cucumbers above.
	Point-rot in hothouse	Mulch or sub-water	An insufficient water supply seems favorable to development of point-rot of green tomatoes.
Turnip	Club-root	Quicklime in soil	As for cabbage and cauliflower. Avoid succession of these crops.
Violet	Nematodes in hothouse	Heat soil with steam	The time for prevention is by soil treatment beforehand as for cucumbers above.
Wheat	Anthracnose	Formaldehyde	Sprinkling as for stinking smut may prove partial remedy.
	Loose smut	Modified hot water	Soak seed four hours in cold water, let stand four hours more in wet sacks, immerse five minutes in water at 133 degrees Fahr. and dry.
	Stinking smut	Formaldehyde, hot water or copper sulfate	Sprinkle grain in piles with formaldehyde as for oat smut, 1 gal. or less per bushel and dry in same manner. Dip skimmed seed for ten minutes in hot water at 133 degrees Fahr. and dry on disinfected surface or immerse ten minutes in solution of blue vitriol (copper sulfate); dry with air-slaked lime by shoveling. Use two pounds of blue vitriol to ten gallons of water. Grain may be sprinked in piles with copper sulfate or formaldehyde as for oats. (See Bulletin 97).
	Insects in stored grain	Bisulfid of carbon	Place one pound of bisulfid of carbon for each 2,000 pounds of grain in bins. Cover surface with blanket to hold the fumes which will spread through the mass, killing all insect life. Use in tight bins or buildings and do not use near fire of any description.

ROOT DISEASES AND ROOT-ROT FUNGI OF ORCHARDS

Diseases upon the roots of herbaceous plants are very commonly due to soil infesting parasites. As explained under that topic, the soil conditions may be favorable to certain parasitic organisms or without being especially suited to them soils become infested with fungi which tend to remain indefinitely and become a source of loss in crops and effort. See lettuce rosette, tobacco root-rot, potato dry-rot and root-rot of violet.

The root-rots of woody growths are commonly more or less truly wood invading fungi of the semi-parasitic type and become of interest to foresters as well as orchardists. A partial exception to this wood-invading character of these root-rot fungi is found in a recently discovered development of the tobacco and violet root-rot fungus, *Thielavia basicola* Zopf., upon catalpa seedlings in nursery. However, since even tree seedlings in their early stages have not developed their woody tissues to any great extent, they are susceptible to the same root parasites as are found on herbs. This will likely explain cases like that cited on catalpa and the trouble may pass as the seedlings become older. Yet it must be confessed that this still raises a question as to the effect of the general parasitism of even Thielavia upon the rootlets of trees like catalpa.

In forest woodlots, root-rots are likely to become of increasing effect. Wherever these tend to limit the reproduction of certain species in the woodlot, they will be injurious. In this respect they may prove an added reason for the rotation of conifers with deciduous growths. In coppice or cut-over lands such as prevail in the charcoal furnace districts of Ohio, the roots and stumps of the parent stem must be an eventual menace to the new growths which spring up about them. The exposure to the wood fungi which become timber or heart-rot sorts will be very great in all such cases. The gradual invasion of the new growths must often occur when these approach a size that gives a considerable heartwood cylinder. These are the great sources of trouble in coppice reproduction of timber trees.

Root-rots in orchard plantings are known more especially when these are made following oak and other species somewhat after the manner of coppice conditions. The rhizomorphic development of these root-rots is difficult to determine but is usually referred to *Agaricus melleus* (*Armillaria mellea*). See root-rots of apple, peach, etc.

An especial feature to be noted in root-rots of all sorts are the soil conditions as to excess moisture and aeration of the soil. In silty or clay soils of close texture and coagulable nature, with excess moisture, serious conditions arise. Any traces of root-rot fungus

under such conditions will involve increased risks. The necessity for drainage will usually be apparent and due consideration of the limits of certain orchard trees needs also to be given. Cherry trees and even peach and apple trees will not survive under moisture conditions wherein plum and pear trees may grow with profit.

Orchard replants in "clinker" locations wherein failures have been numerous, will raise these questions of root-rots and relative adaptability of different orchard trees. Rotation planting, as pear or plum after apple, plum after cherry, etc., may at times succeed and replace unsightly gaps in the orchard by flourishing trees of another sort. At present, drainage and aeration are our known methods of restricting root-rots under out-door conditions.

PARASITIC FOLIAGE DISEASES

Foliage diseases of every sort are caused by oxygen loving or aerobic species of parasites, and very often this development on the leaves consists of the imperfect forms of the fungus life history. These forms are none the less aggressive and injurious for this reason, but the exact manner of survival from year to year becomes important wherever not known. The application of this to preventive measures in the control of these diseases upon foliage and fruit is seen in the case of apple scab, the monilia rot of plums, peaches, cherries, etc., and in apple bitter-rot. These last two rot troubles survive in the "mummy" or dry rotted fruits and this explains the reason for the oft repeated injunction to destroy all "mummies" in addition to spraying operations. The bitter-rot of apples is propagated by means of summer branch cankers on the tree, as brought out in recent years. Other leaf forms survive on the fallen leaves or possibly in bud scales as with the leaf curl and "bladders" of the *Exoascae.* A large number must live over on the branches.

Parasites upon foliage soon become apparent from the spots on the leaves and dropping of fruit resulting. This dropping may come as a result of impaired vigor by reason of disease—then it is later, but is more often the direct result of parasitic attack by the disease upon the young fruits. Herein as elsewhere the philosophy of fungicides comes to our relief. A good foliage fungicide is a relatively insoluble compound which will not greatly injure the leaves with which it is in contact. The remedies for foliage troubles are applied in *anticipation of attack* and for the purpose of checking the fungus when it may appear. The relative efficiencies of various fungicides in early summer will possibly depend upon the sticking qualities of the sprays.

Foliage diseases, moreover, are liable to recur each year and this is an added reason for anticipatory treatments to ward them off. *Foliage diseases may not be neglected with impunity since the leaf is the plant's vital working organ and the plant must suffer from its impairment.*

BITING AND SUCKING INSECTS AND LEAF DISEASES

The part played by insects which wound the leaf epidermis, in the spread of leaf diseases, is often very important. Such wounding of the leaf or green stem whether by insects such as flea beetles, foliage eating worms, or by sucking insects such as mites, leaf hoppers and plant lice, opens the way for the spores of parasitic fungi or of bacteria or mere molds, any one of which may be injurious to the leaf. The early blight disease of potatoes is a good example. In seasons when there are many of these little black flea-beetles to puncture the leaves, the thorough control of both these insects and the early blight, *Alternaria* fungus, is called for. Many fungi of doubtful penetrating powers are truly injurious when they follow insect punctures of the leaves. Fortunately both these are secured by Bordeaux sprays. The reasons for such applications are of double character since they are to combat both the insect and the fungus to follow it.

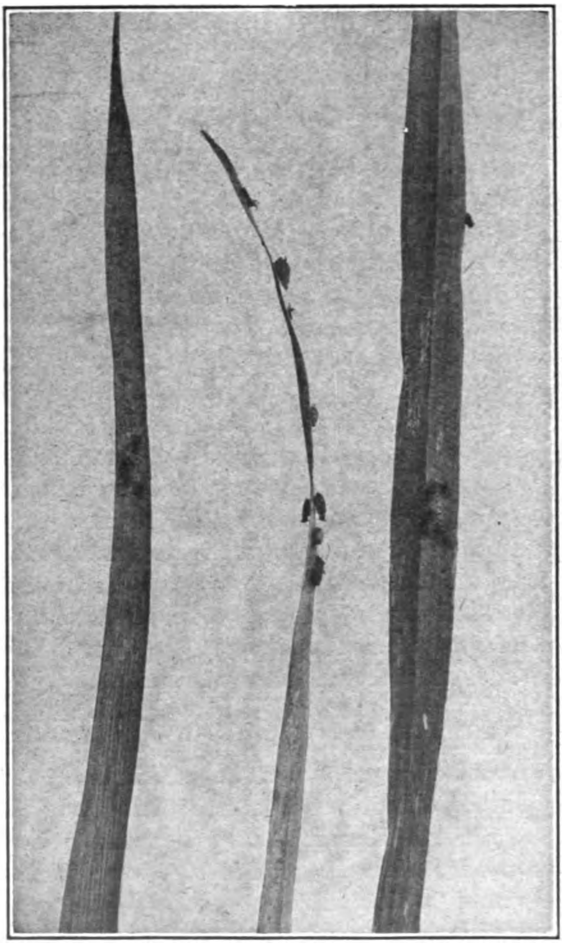

Fig. 22. Showing sections of blades of oats attacked by green lice (aphides). The right hand specimen shows type of injury resulting from the sucking of the aphis. In case these lice are carrying the organisms of oat blade blight, this sucking will lead to infection by the disease. (From a photograph by T. F. Manns).

With shade trees the leaf hoppers and mites may be so numerous that tip-burn and various leaf dying results from the injuries or punctures they inflict.

A more startling relation is that of the blade blight of oats, a recently investigated bacterial trouble. This bacterium is distributed and inoculated very obviously by the aphids or green flies (plant lice), and other sucking insects which prevailed during the seasons of 1907 and 1908 upon oats almost throughout Ohio. For fuller details see Blade Blight under Oats, and Bulletin 210.

Fig. 23. Maple shade tree, Wooster, with large branch cut off. Below this cut the wound fungus, (*Volvaria bombycina*) has developed and fruited; the cap is nine inches across. This shade tree was further wounded by wrappings of wire to stiffen a telephone pole. (From a photograph by J. M. Goheen).

WOUNDS AND WOUND INFECTION

With woody growths, especially in trees which attain considerable size, we have the various phenomena of disease infection through wounds; this infection later becoming evident by reason of decays set up in the woody tissues. Of course, in instances such as the bark disease of the chestnut, *Diaporthe parasitica* Murr., the disease may penetrate the living tissues. Not so, generally, in wounds of woody plants. Any large woody growth, as in forest or shade trees and in larger fruit trees, shows the combination of an external or living sapwood layer and an internal dead or heartwood cylinder. The commoner forms of wound infections are attributable to those species of fungi which cause decay of this dead heartwood. Among these are the long list of saprophytic, agarics, polypores and stereums. Because of the fact that this heartwood cylinder is dead, these saprophytic species of fungi, once they gain entrance into it, flourish there and invade the wood to a very great extent, even by adaptation to parasitic habit extending their work into the living parts causing death. The removal of a large branch of a shade tree or a fruit tree, unless the wound thus

formed is properly protected by dressing, opens the way for spores of these fungi which cause timber decay to obtain a start and thus eventually to invade the heartwood of the interior. For dressing cut off branches, asphaltum is admirable; in its lack gas tar is good, and either is better than ordinary paints.

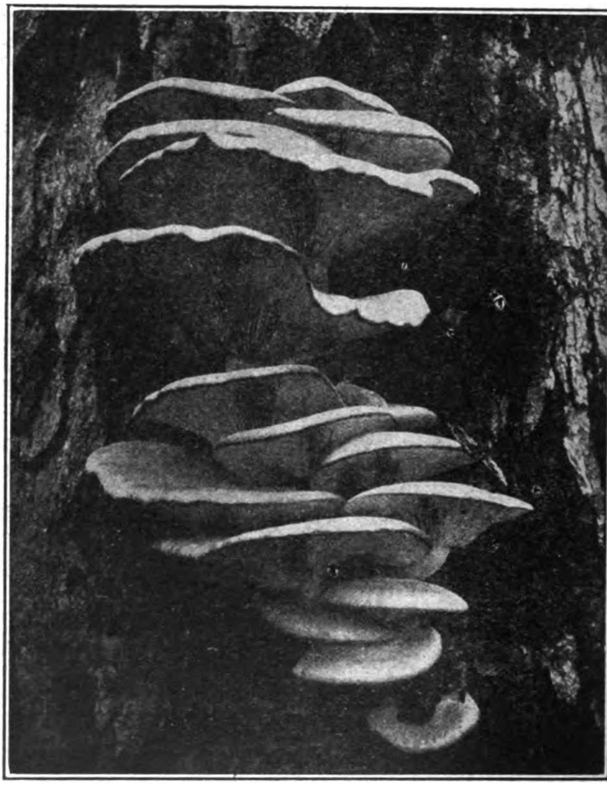

Fig. 24. A wound parasite (*Pleurotus ulmarius*) on the trunk of a maple tree. (After Freeman, Minnesota Plant Diseases).

There is always to be borne in mind that the protection of the woody cylinder of trees depends on its being covered by the living layer of sap wood. Every branch of considerable size connects directly with the extensive heart cylinder; we thus see that the wound fungi which attack the heart wood are the timber decays and their presence emphasizes the need for care in providing protection for all wounds, especially those caused by pruning.

Any decay becoming established in the dead heartwood may extend for long distances through this dead wood and in the end so destroy it as to be in a position to invade the external or sapwood layer.

In addition to the exposure of the internal woody cylinder to these decays, we have sap-rots due to various species of fungi which belong on the border line between the parasitic and saprophytic sorts: Among them are species of Fomes, Polyporus, Lenzites, etc. Any wound of the sapwood even though it does not reach to the dark heart-wood, exposes to the danger of this infection, and with infection, to all the consequences of sapwood decay and premature death of the tree. These decays and those of heart-wood are in line with those of the rots of structural timbers, but we are at this time interested only in their effects on the parts of the living plants.

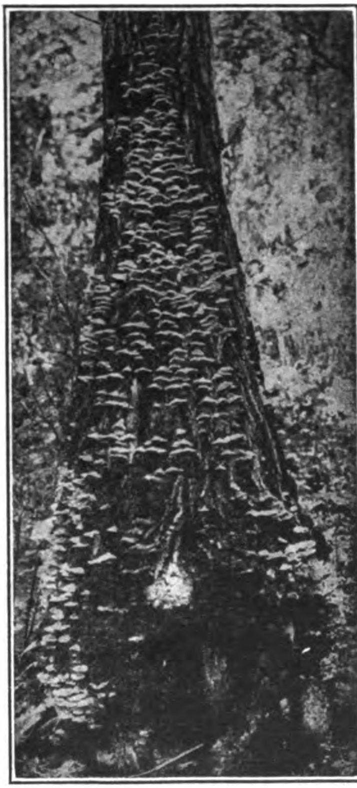

Fig. 25. Another wound parasite (a species of *Stereum*). The fungus obtained entrance in the wound at the base of the tree (an oak), and as shown by the fungus fruiting bodies, is gradually progressing upward. This tree died about a year after the photograph was taken. (After Freeman).

TIMBER ROTS AND TIMBER PRESERVATION

The decay of dead logs, wooden frameworks, or other structural timbers is caused by the attacks of saprophytic fungi belonging to the gill and pore fungi mentioned under wounds; these are of the great class of basidium bearing fungi, to which the fleshy forms, everywhere more or less abundant, belong. The most of them are included in the "mushrooms," which there is a strong impulse now to study and illustrate by photographs. These timbers are dead and are subjected to invasion by timber infecting species wherever the conditions as to air and moisture are such as to favor their development. Dry timbers are not subject to such attack because lacking the requisite moisture for the organism. Floors and other timbers of houses adjacent to the earth or to unheated cellars are often attacked by rot-causing species. The timbers of trestles, railway ties and the bases of fence, telephone and telegraph posts, where inserted into the earth or in contact with it, are kept sufficiently moist to invite attacks of this sort.

Wood that has been invaded by such fungi is reduced to the state called punk: that is, the wood fibers and arrangement in vessels to which the timber owes its strength, are broken down by the invasion of the fungus which flourishes at the expense of this woody tissue. There is no help for timber after it has once been attacked by rot fungi. Whatever preventive measures are taken must precede the attack. The most effective means of timber preservation is to cause it to be injected or permeated with creosote or other antiseptics. This is done by placing the timbers in vats containing the solution and extracting the air from the timbers so far as possible. The permanence of the effects of such timber treatment depends upon the resistance offered by the material used to gradual solution by water. In the case of creosote the results are quite satisfactory; with chlorid of zinc, subsequent solution takes place too readily, while with crude petroleum there is a tendency toward the evaporation of this substance when injected. The increasing cost of timber will stimulate timber treatments by making treatment profitable. One drawback at present is the necessity to import creosote for use in such work; possibly refiinery by-products from petroleum of a character analogous to asphaltum may find application in timber treatment.

Fig. 26. Fruiting bodies of the fatty Pholiota (*Pholiota adiposa*), in a wound of an oak tree trunk. (After Freeman).

ATMOSPHERIC CONDITIONS AS AFFECTING PLANT DISEASES

The relation between weather and the prevalence of certain plant diseases has been often recorded. The diseases which prevail are none the less parasitic, the difference exists solely in the temperature and moisture conditions of the atmosphere. Here we must distinguish clearly between the *cause* of the diseases and the *conditions* which favor the given diseases.

Certain parasitic fungi develop more rapidly under cooler conditions than the normal or average while others are favored by higher temperatures; all fungi are favored by large amounts of moisture when these stop short of water immersion and shutting out the needed air. In temperature we have an optimum which usually lies within certain maximum and minimum limits for any given species, but this temperature optimum varies with the organism; it is a matter which admits of exact determination for any organism. As to moisture, an abundant supply of water is the optimum for most fungi with which we deal in plant disease investigations.

In these atmospheric conditions of temperature and moisture the seasons of the year, in our climate, vary one with another. The seasons of heavy rainfall are commonly those of low temperatures by reason of the check on temperatures exerted by evaporation. Further, our weather service records show a tendency for our seasons to come in groups of cooler alternating with groups of warmer seasons; that is, we may have several years as with 1904 to 1907 (excepting parts of 1906) in which the mean monthly temperatures of those months which affect crops were decidedly below the normal or average. Evidently this normal lying as it does between the extremes, is surpassed by the warmer seasons which are said to be above normal. We have likewise, other alternating groups of years in which the season's temperatures are decidedly above the normal.

The effects of these cool seasons upon diseases are most clearly shown in outbreaks of leaf-curl of the peach and plum bladders in early season, and of potato late blight and rot, *Phytophthora infestans*, upon the potato crop. It is understood that plenty of moisture is the usual accompaniment of a cool season; from the combined effect of this supply of moisture and cool weather we have outbreaks of the potato disease even in northern Ohio where it does not appear certainly to survive from year to year. Such groups of cool seasons culminate as a rule in particularly injurious outbreaks of the potato Phytophthora with us; in more northerly situations, the disease is present nearly every season, but the outbreaks culminate with favorable weather conditions of excessive rains and lowered temperatures.

Stress has been laid upon the downy mildew of potato and cucumber respectively. It must not be inferred that other diseases do not offer like contrasts between dry, hot seasons and those of heavy precipitation and low temperatures accompanied by relatively high atmospheric humidity. Mention has already been made of the greater prevalence of the shot-hole disease of the plum and leaf-spot of cherry, *Cylindrosporium padi*, in rainy seasons over drier ones. The same facts will apply with respect to practically all external parasites of plants as in the scab fungus on the apple, the rot of plum, cherry and peach, and to the countless number of foliage diseases with which we deal from year to year.

Contrasting with the potato Phytophthora is the allied disease of curcurbits, the downy mildew, *Plasmopara cubensis*, which appears to flourish during our hot seasons and to disappear during the cool ones where grouped as above described. The writer has suggested that this Plasmopara does not survive in our climate but is carried northward each year by its conidia alone; the extent of spread will thus be limited by the length of period favorable to it. This period must be one of relatively high temperatures since this parasite is more widely distributed near the tropics. All these instances only make more clear the intricacies of the mutual adaptations of parasite and host which have resulted from the long periods in which these dwell together.

MEAN SUMMER TEMPERATURES AND RAINFALL IN OHIO, 1883-1909

Year	Mean temperatures degrees Fahr.					Mean Rainfall, inches				
	May	June	July	August	Three months Mean	May	June	July	August	3 Mos. Total inches
1883	58.0	69.0	72.1	68.2	69.8	5.72	4.25	4.16	1.88	10.29
1884	60.4	71.1	71.5	70.8	71.1	3.87	2.96	3.83	1.45	8.24
1885	59.5	67.1	75.2	68.9	70.4	3.97	4.34	3.20	6.33	13.87
1886	62.2	67.5	72.0	70.9	70.1	4.23	3.53	2.88	3.62	10.03
1887	66.0	71.0	77.9	77.9	75.6	2.87	3.85	2.16	2.39	8.40
1888	58.8	70.4	72.1	70.4	71.0	3.77	3.41	4.40	5.16	12.97
1889	60.2	66.7	72.5	69.1	69.4	3.71	4.13	4.25	1.50	9.88
1890	59.2	73.3	73.0	68.8	71.7	5.52	4.50	1.99	4.70	11.19
1891	58.0	71.0	69.0	70.0	70.0	2.20	4.82	3.82	3.07	11.71
1892	59.0	73.0	73.0	71.0	72.3	6.32	5.61	3.80	2.99	12.40
1893	58.3	70.6	74.5	70.7	71.9	4.97	3.34	2.49	2.17	8.00
1894	60.0	71.3	74.3	71.2	72.3	4.00	2.65	1.56	1.67	5.88
1895	61.1	72.0	71.6	73.5	72.4	1.80	2.47	2.00	2.96	7.43
1896	67.9	69.5	73.2	71.8	71.5	2.67	4.81	8.11	3.38	16.30
1897	56.3	68.1	75.5	69.4	71.0	3.93	2.85	4.65	2.72	10.22
1898	61.0	71.9	76.0	73.5	73.5	4.10	2.86	3.98	4.50	11.34
1899	63.3	71.5	74.1	73.7	73.1	4.32	2.96	4.18	1.82	8.96
1900	62.9	69.8	74.1	76.3	73.4	2.40	2.99	4.62	3.68	11.29
1901	59.0	70.9	78.1	73.1	74.0	3.69	4.38	2.73	3.32	10.43
1902	62.6	66.9	74.0	67.4	69.0	3.09	7.48	4.69	1.67	13.84
1903	63.9	64.4	72.9	70.7	69.3	2.82	3.97	3.67	3.20	10.84
1904	60.7	68.4	71.4	68.8	69.5	3.79	2.88	4.13	2.74	9.75
1905	60.7	69.2	73.0	71.7	71.3	5.63	4.72	3.93	4.46	13.11
1906	61.3	69.8	72.1	74.6	72.2	2.17	3.41	5.14	4.77	13.32
1907	54.5	65.6	72.6	69.5	69.2	3.47	4.57	5.36	2.48	12.41
1908	62.8	69.2	73.9	71.2	71.4	4.72	2.52	4.08	2.59	9.19
1909	58.7	70.1	*69.6	*70.3	70.0	4.72	5.86	*4.05	*5.21	5.04
Ohio, '83-'09	60.6	69.6	73.44	71.3	71.4	3.88	3.93	4.08	3.12	10.88

* Records Wooster only, not included in other than 1909 averages.

The blade blight of oats, a bacterial disease, has been found to be much influenced if not largely controlled by atmospheric conditions and perhaps more especially those of the earlier summer. These factors have been recently presented by a bulletin of this Department (See Bulletin 210). This publication contains a fuller table with respect to early summer atmospheric conditions. The development of the Fusarium blight and dry-rot fungus as a widespread and serious disease of potato plants causing premature dying and reduced yields is of interest here. The outbreaks in Europe seem to be associated with atmospheric conditions in spring and early summer. We need fuller studies on these inter-relations.

Insistence is here again made upon the observed relations between atmospheric conditions and parasitic diseases of plants that the grower may be stimulated to greater effort at close observation when the need exists and the student may be aided in his interpretation of the vast array of apparently inconsistent and complex facts by which he is to be instructed.

REMEDIES FOR PLANT DISEASES--FUNGICIDES

In no other line of applied science has America made more rapid progress than in the matter of plant disease remedies. While the general doctrine of parasitism and the transmission of parasitic diseases are thoroughly investigated and widely published in Europe, the application of remedies and the interest in disease prevention fall much behind the practices in America. Indeed, the writer's attention was in 1908-9 forcibly called to this matter by the statement of a prominent American Pathologist as to the relatively great advancement in America over the old world in this regard. Probably this greater progress is due to the greater readiness with which Americans engaged in crop production, accept the teachings of scientists and make practical applications of the results obtained.

Among remedies for plant diseases we must include all treatments which tend to restrict or prevent the recurrence of diseases, that is, all treatments which remedy infections or limit the spread of parasitic attack.

SEED AND SOIL TREATMENT

Seed and soil treatments naturally belong here; while somewhat full discussion has been given on pages 342-345, it is necessary to recall the measures employed in seed treatments as well as in soil disinfections. In the seed treatments high temperatures, as in the hot water, or the application of a germicide as in solutions of formaldehyde are applied to the seed grain to destroy adhering

spores. In the treatment of tubers and roots as the potato, etc., longer soakings with solution of formaldehyde or corrosive sublimate are required to kill not only external spores but resting forms of fungi such as sclerotia, etc.

With soil treatments we have the problem of killing out soil infesting organisms such as nematodes or eelworms and Rhizoctonia, Botrytis, lettuce drop, etc., among the fungi. All these results are obtained by thoroughly steaming the soil. In a measure the same results are also obtained from a formaldehyde drench as elsewhere described.

Fumigation for the destruction of seed infesting fungi or cutting infesting insects is of the same character and must be named here. The fumigation of nursery cuttings with hydro-cyanic gas is effective as is also the fumigation of stored grain with carbon bisulfid. We must also consider that wound coverings are methods of prevention in plant disease, since these coverings of asphaltum creosote, gas tar, paraffine and even of paint serve the purpose of excluding wound fungi which might otherwise cause serious decays. All these treatments that have just been enumerated apply to the treatment of the soil or of seeds and plants in resting condition. The great problem of keeping down infection during the growing period yet remains for the application of spray mixtures.

SPRAYING WITH FUNGICIDES--INSOLUBLE COPPER COMPOUNDS

The progress made in the control of plant diseases through sprays since Millardet's discovery of Bordeaux mixture (bouillon bordelaise) near Bordeaux, France, in 1883 shows how great was then and is still, the need for effective fungicides. The materials from which Bordeaux mixture is made consist of copper sulfate (blue vitriol) calcium oxid and hydroxid (caustic lime) and water. In the making of the mixture the copper sulfate is dissolved in water and should be diluted with a considerable amount of water; the lime is slaked or converted into lime putty from which a milk of lime is prepared. These two mixtures with the copper sulfate in aqueous solution and calcium hydroxid in suspension, mixed together make a chemical reaction by which the calcium in the lime displaces in part the copper in the copper sulfate, forming on one hand calcium sulfate or gypsum, and on the other the various combinations of lime with the metallic copper thus liberated. The actual reactions have been variously interpreted. More recent investigations show that several basic sulfates of copper and lime are produced. Whether any hydroxid of copper is produced has been questioned by Pickering, an English investigator. The light blue color is due to suspended

particles of these compounds which are evidently the effective agents in fungicidal action. These insoluble light blue copper compounds which, in this divided condition, are held in suspension in the liquid give it the characteristic color. The essential needs in making Bordeaux mixture are the presence of enough or even an excess of the base, calcium (lime), so that none of the copper will remain in soluble form as sulfate. This on the other hand involves the more or less complete change of the soluble copper into relatively insoluble, blue-colored copper compounds of another sort.

The philosophy of spray action is based first of all upon the absence of injurious effects from the lime products and from the copper compounds produced, when sprayed upon green foliage. In the second place, upon the effectiveness of these insoluble copper compounds through solution in the presence of moisture and carbon dioxid in the atmosphere, to destroy or prevent the growth and development of parasitic fungi. The time during which these insoluble copper compounds will be effective must depend upon the rate of growth in the plant parts and the adhesiveness of the application. The essential feature to be remembered is this; the insoluble or slowly soluble copper compounds become available by solution as needed. Where excess of fungicide is employed this has a certain danger upon apple or other foliage during showery weather and in all cases the strength is adapted to the host crop. Coincident with the spraying period there is frequent complaint of injury to apple foliage. Here we have solution effected more rapidly than is safe for the host; normally this risk is slight, but may be overcome by necessary modifications. Another matter is the amount, the number of gallons of the given fungicide to use; with more complete spraying appliances and high pressure of application, larger amounts and more complete covering of the parts are the rule. Recent results show that when the amount of copper in the mixture is near to the danger line these heavier applications increase the risk.

In the early translations from the French the strength of Bordeaux mixture was placed higher than is now the practice. For Ohio the following formula has been the rule for many years:

STANDARD BORDEAUX MIXTURE

Copper sulfate (blue vitriol)..............................	4 pounds.
Caustic lime (unslaked)................................	4 pounds.
Water to make..	50 gallons.

This is a 4-4-50 formula—a 2-2-50 formula is also used at times.

In making Bordeaux mixture, the copper sulfate may be dissolved in hot water (about 2 gallons) or better by suspending the sulfate contained in cheese-cloth sack, in a large vessel of cold water.

By using large quantities of both blue vitriol and water, say 50 pounds of copper sulfate and 50 gallons of water, a stock solution may be prepared, so that each gallon will contain one pound of the blue vitriol. In each case the solution of copper sulfate should be diluted say to one-half of tank capacity before admixture with the milk of lime.

The quicklime is slaked and then stirred to make milk of lime, adding water as needed to do this. The necessary amount of this milk of lime should be diluted to about 40 or 50 percent of the tank capacity and then run into a mixing tank with equal flow of corresponding volume of copper sulfate solution *before same is run into spray tank or barrel.*

All Bordeaux mixture formulae are useful as a vehicle in which arsenical sprays are added to serve as insecticides.

THE USE OF STICKERS IN SPRAY MIXTURES

Some experiments made in different parts of the country have shown beneficial results from the use of other materials added, such as sugar solution, soap, resin soap, etc., to increase the adhesiveness of the spray. In some spraying experiments by the Entomological Department of this Station, laundry soap was used effectively as a sticker to hold arsenical compounds in checking the berry worm or grape worm (See Circular No. 63).

The writer has proposed a modification of Bordeaux mixture which has been called "Bordeaux Mixture and Iron Sticker."

The following formula has been recommended:

BORDEAUX MIXTURE AND IRON STICKER

Copper sulfate (blue vitriol)	2 pounds.
Iron sulfate (copperas)	2-4 pounds.
Caustic lime	4-6 pounds.
Water to make	50 gallons.

In this spray the iron sulfate is added in order that it may be precipitated by the lime and serve as a more complete sticker than is provided by the standard Bordeaux mixture. It would appear possible by the weak solution as given for the copper compound and by this possible efficient sticker to make the reduced amount of the copper sulfate do the work as fungicide just as effectively and with less risk of foliage injury than with the standard Bordeaux mixture. The trials made up to this time upon apples in full foliage, upon grapes and upon potatoes indicate that the spray is efficient. *The iron sulfate is not considered a fungicide.*

SOLUBLE COPPER COMPOUNDS AS SPRAYS

Whenever it becomes necessary to continue spraying upon fruit as ripening approaches a more soluble copper compound than Bordeaux mixture must be employed or the spray will remain upon the fruit at marketing. The remaining spray, if excessive, injures the marketable character of the crop. Various sprays have been proposed for use at these critical times. The call for them has come in keeping down the black-rot on the grape ana in the control of the several late season diseases of fruit, like the bitter-rot and black-rot of apple. The most satisfactory soluble copper sprays appear to be ammoniacal solution of copper carbonate or Soda Bordeaux mixture.

For the former the following formula is given:

AMMONIACAL SOLUTION OF COPPER CARBONATE

Copper carbonate	6 ounces.
Ammonia	about 3 pints.
(Enough to dissolve the copper carbonate and no more).	
Water to make	50 gallons.

This is an effective spray made according to formula for the late applications upon grape and upon apple as maturity approaches. It is to be understood that this formula is not intended to make "eauceleste" which is a different preparation. No more than enough ammonia is added to convert the copper carbonate from insoluble to soluble form in the presence of water. A soluble salt of ammonia and copper is really produced. The proper times at which to make applications of fungicide as sprays has been carefully worked out in practice and directions are included in the spray calendars. There is a good reason in nearly every case for making the applications at the time recommended, since these sprays are timed to check the development of the parasite; if put on too long in advance the spray may be displaced, if put on too late the damage will occur without a possible means of prevention. All sprays as stated before are made in anticipation or in advance of actual danger from parasitic diseases.

SULFUR COMPOUNDS AS FUNGICIDES

Various preparations of the sulfids of alkalis and alkaline earths have been proposed as fungicides. A larger use has been made of the lime-sulfur formulae which have come into use largely for checking scale insects. These mixtures are made by boiling together caustic lime and flowers of sulfur in the presence of water. By this heating process a combination is effected between the calcium and the sulfur, and sulfids of various compositions are formed. For practical purposes the color reactions are used as a guide. This spray applied

in the dormant period or just as the buds are swelling is effective against the scale insects and is also efficient as a fungicide. The lime-sulfur has very largely displaced other fungicides against leaf-curl of the peach. More recently the self-boiled lime-sulfur formula has been proposed. It promises to be effective upon peach trees in foliage. This is a much more dilute formula than the one used upon dormant trees; both are described in the spray calendar. Latterly, various dilutions of the lime-sulfur residues formed when lime and sulfur are boiled together, have come into use as sprays for orchard use.

SOLUTIONS FOR SEED TREATMENTS AND DISINFECTION:

FORMALDEHYDE SOLUTIONS

Formaldehyde in 40 percent solution is obtained upon the market. Solutions of this 40 percent compound in water are effective in seed and soil treatments and for disinfection. The following are standard strengths:

For oats and wheat, 1 lb. or pint 40% formaldehyde to 40 or 50 gals. water.
For potato scab and rosette, ½ pint of formaldehyde to 15 gals. water.
For onion smut, 1 lb. of formaldehyde to 25 or 33⅓ gals. of water.
For soil drench, 2 to 4 lbs. of formaldehyde to 50 gals. of water.

CORROSIVE SUBLIMATE SOLUTION

For treatment of potato tubers and for laboratory disinfection, mercuric chlorid, corrosive sublimate, is used as follows:

Corrosive sublimate	2 ounces.
Water	15½ gallons.

GASEOUS DISINFECTION WITH FUNGICIDES

Latterly the methods used for the disinfection of houses wherein patients have suffered from contagious diseases such as diphtheria, scarlet fever, etc., have been extended to the treatment of plant diseases. The following formula of the Maine Board of Health is applicable to the details below given:

FORMALDEHYDE GAS

Commercial 40% formaldehyde	3 pounds.
Potassium permanganate crystals	23 ounces.

Sufficient for 1000 cu. ft. of space occupied by crates or trays.

The following suggestions from the spray calendar of 1908 will be helpful to students or experimenters who have not access to other literature:

"Enclose open tiers or piles of slat crates filled with dry onions, potatoes, etc., in tight room or oiled tent of canvas buried in earth about the base. Generate the formaldehyde gas in a flat bottomed

dish or pan of adequate capacity by placing one of the materials, as the liquid formaldehyde, in the pan, and adding the other the last thing before retiring. Then close tight and allow to remain closed 24 to 48 hours.

Proportionate or multiple unit amounts may be taken for smaller or larger enclosed spaces. Applicable to fumigation of seed potatoes for scab, sweet potatoes for rot troubles and to newly gathered, dry onions before storing for winter.

For grain elevators to disinfect against conditions there or for mass treatment of seed oats and wheat a similar use is made of formaldehyde gas.

ROT DISEASE LOSSES IN STORAGE

No sharp line can be drawn between diseases of edible plant products which usually infect these crops previous to harvest, and the rots, molds or decays in such fruits and vegetables during storage. It has seemed best, for this reason, to insert here a brief discussion of these storage troubles which apply to products grown in our region. We can scarcely be called on to present the facts concerning the diseases of citrus fruits in storage or in transit.

All growers of fruits and vegetables in our state are liable, however, to have had losses from rots of fruits and vegetables during storage upon the farm. In the more recent custom of concentrating such storage products in cold storage plants, especially constructed for that purpose, the problem has only been transferred or transplanted: the difficulties have not been entirely overcome.

For the fruits known as perishable, namely, for peaches, plums, cherries and grapes, the custom of brief storage has become well established; the rots or other injuries, such as those that come from crushing, are well known. The storage rots are not different from those commonly found in the orchards—indeed, they are usually the common soft-rot of stone fruits, *Monilia fructigena*. Storage or transit losses from it are but an accentuation of orchard conditions. Also with the stone fruits, as a result of bruising and shipment, we have various of the common molds which develop on the bruised surfaces. The more usual ones are the common bread mold, *Mucor*, the blue mold, *Penicillium*, or the almost equally frequent form of green mold, *Aspergillus*. None of these, however, is likely to penetrate very deeply and be a serious enemy of these fruits. This arises, however, not so much out of the lack of ability to injure by these mold attacks, as from the very brief period of time which these tender skinned stone fruits are held before consumption. As has been pointed out by Powell and Smith, the

same common molds, including especially Penicillium, possibly with the aid of others, are sources of serious loss in the handling of citrus fruits—oranges, lemons, etc., during their prolonged periods of transit and storage.

In the case of grapes the losses are almost altogether due to breaking of the skin following which molds and bacteria are liable to appear under favorable conditions.

STORAGE ROTS OF APPLES AND PEARS

With apples the commonest storage rot for our district is doubtless also the commonest orchard rot, namely, black-rot, due to the black-rot fungus, *Sphaeropsis malorum* Berk. All are familiar with orchard conditions liable to prevail at ripening time. This fungus is generally found, especially in orchards of mixed varieties, because some sorts are commonly attacked by it. The same fungus causes cankers upon branches of the susceptible varieties and is usually well distributed over orchards. The punctures of worms or of bees, or wounds caused by mechanical injuries such as occur in wind-falls, and the various drops at picking time, afford easy entrance for the fungus. In consequence we must expect that the fruits which have been in any way punctured or injured, have also been exposed to infection by the black-rot fungus. Such infected fruits are very liable to rot because of the progress of the fungus, if conditions are favorable. The high temperatures of storage sheds and ordinary freight cars during October and early November in our climate, are such as favor its development.

In the light of our present knowledge the best we can do is to transfer fruit as soon as possible to storage where the temperatures are low enough to restrict the fungus. It follows without saying, that good results are obtained only from absolutely sound fruit, and the low temperatures of cold storage houses, 42 degrees or below, may be relied upon to check this rot to a very large extent, provided only sound fruits are placed in storage.

Naturally the discussion which follows under the storage of onions will raise the question here as to the practicability of gaseous disinfection of apples by the use of formaldehyde gas. It would seem possible under favorable weather conditions when fruit can be gathered dry and brought into storage houses in that condition, to disinfect the fruits by the formaldehyde gas method. Of course it follows that the period of disinfection will be brief in order that little or no gas will be absorbed by moist or exposed fruit surfaces, since formaldehyde is objectionable in foodstuffs. The time of fumigation may not need to be more than about half that used for potatoes or onions, and the strength of the formula may even be modified. The aim would be the destruction of external spores, etc., which certainly are a menace at all times.

The bitter-rot fungus, (*Glomerella rufomaculans* (Berk.) Von Schrenk) may also develop in storage apples where these have become attacked by it before harvest. The bitter-rot may be more common upon late summer and fall varieties in transit, than in ordinary winter storage. Certain sweet apples, such as Bentley Sweet, are very susceptible to bitter-rot losses in storage. Cold storage temperatures hold back the development of the fungus, but cannot disinfect the diseased fruits.

Pear rots with us are almost exclusively those which occur in the orchard. The leaf-spot fungus (*Entomosporium maculatum* Lev.) also attacks the fruits of pear and may become a source of loss in storage. This applies more particularly to inferior grades of fruit. Pacific coast fruit which is shipped to our district, may further suffer from some of the ordinary molds which find access to the fruit entirely through bruised or other injured areas.

The brief storage of quinces usually does not lead to much further development of the quince rot. The fungus in question is commonly the same as that in the apple rot, (*Sphaeropsis malorum* Berk.).

STORAGE ROTS OF POTATOES, ONIONS, ETC.

With vegetables we have a very wide range of storage troubles. In the case of potatoes we have two general types of rots, namely; wet-rot and dry-rot. The wet-rot of potatoes commonly results from two causes, viz.: The late blight or rot fungus (*Phytophthora infestans* D'By.) may be expected to cause considerable losses of the tubers in storage when these have been gathered from Phytophthora infested fields and bacteria may cause rot in injured tubers. In Ohio, as stated under this disease of potatoes, the late blight and rot fungus is not commonly prevalent. Perhaps little can be done to preserve the tubers from such fields except to market the crop promptly and to store with especial respect to the optimum conditions. The best temperatures for such potatoes will be warmer than for apples, and it is very desirable that moisture be kept as low as possible.

A wet-rot of potatoes, purely or very largely bacterial in cause, must also be dealt with. This rot bacterium is different from the bacterium of potato wilt, (*Bacillus solanacearum*) and without the latter may also induce considerable decay. It is believed the bacteria producing this wet-rot gain entrance through injuries to the tubers and that low humidity—dry storage—is especially desirable in keeping down losses from this source.

Dry-rot of potatoes is due to a fungus (*Fusarium oxysporum*) which appears to belong among our soil infesting fungi. This fungus appears to be the cause of premature dying of the potato plants and it certainly survives in the tubers from such infected plants. At harvest time, as shown under dry-rot of potato, tubers show infection at the stem end. Subsequently during storage the fungus penetrates more deeply into the tubers and will often produce dry-rot of the infected tubers. Further descriptive matter concerning dry rot will be found in the special part of the bulletin under potato. For storage of such infected tubers, as well as for the general crop, it is desirable that storage temperatures be kept about 42 degrees Fahr., or slightly lower.

Sweet potatoes also suffer from a large variety of rot troubles. These sweet potato rots are more or less special in character and since the crop is not largely handled in cold storage, nothing is here offered in addition to what appears in the special part of the bulletin

ONION ROTS IN STORAGE

Onion rots are a serious matter with onion growers and onion dealers as well. It has been found that particular varieties of onions in our climate are susceptible to special diseases. For this reason we must consider white onions such as White Silverskin, White King, etc., in a separate class from the rots of red and yellow onions such as the Globe and Wethersfield varieties.

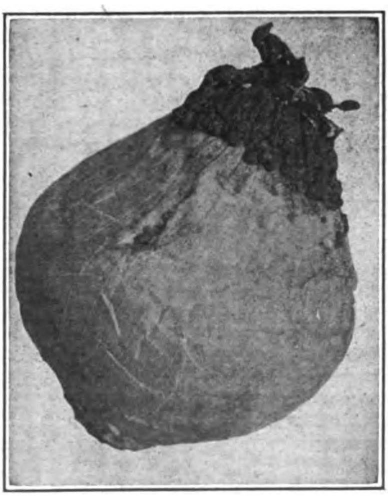

Fig. 27. A white onion that has been destroyed by a blackneck or dry-rot fungus, *Sclerotium cepivorum* Berk. This parasite has entered the onion through the green neck which was cut off at the time of harvesting the crop. (From a photograph by T. F. Manns).

With the white onions the problem is partly a field problem at harvest time, and partly one of storage. The growers are in the habit of gathering the white onions before the tops fall and topping them immediately, instead of throwing together in heaps for absorption of the substance of the tops by the onion bulbs as is practiced with the riper red and yellow varieties. After topping the white onions are placed in slatted crates, and these crates are stacked in the field or in open sheds where they are kept dry. Often the loss from rot during the six weeks following harvest may reach 60 percent of the

crop, and as shown by investigations in Connecticut and our own state, it has not always been clear why these losses are so large. Recent investigations by this department lead us to believe that the green onion neck of white onions handled in this way affords entrance for the organism of the rot.

The sclerotium rot (*Sclerotium cepivorum*) appears to be the most serious, although smudge or anthracnose of the onion (*Vermicularia circinans*) may sometimes cause large losses. Both these rots are described under diseases of the onion. The writer believes the Sclerotium rot is the larger criminal, and that both may be handled by disinfection of the onions immediately after harvest. This disinfection may be carried out as described under the Maine formula for Formaldehyde gas treatment, which is:

Commercial 40 percent Formaldehyde............. 3 pounds.
Potassium Permanganate crystals... .... 23 ounces.
Sufficient for 1000 cu. ft. of space occupied by crates or trays. (See page 360).

The object of immediate disinfection is to prevent the entrance of these organisms, particularly the sclerotium rot, through the green neck of the newly topped onions. The exuding juices offer favorable culture conditions for the fungus to develop.

When no fumigation is practiced following harvest, the onions which are found to be sound and delivered for storage at the close of the season may very profitably be treated in this way before winter storage. Both these rots are essentially dry-rots of onions. In addition, sometimes, we have wet-rot of white onions which may be either due to bacteria or to the same fungus as the wet-rot of Globe or other onions mentioned below.

The rots of yellow and red onions are of both the wet-rot and dry-rot types, but the wet-rots are much more serious with these varieties. Doubtless, as in all vegetables held for a long time in storage, we have many cases of wet-rot in onions where some of the common decay bacteria are the chief cause. These find entrance through wounds, as in topping, and, under conditions favorable for their development invade the tissues of the onion and cause decay.

In addition however, to the wet-rots due to bacteria of undetermined species, we have a specific wet-rot of onions due to Fusarium species. This wet-rot fungus belongs to the same group as the potato dry-rot and is liable to infect soils in which onions are grown year after year. Rotted onions will show external developments of the pink fungus and may be detected in that way as well as by use of the microscope. The chief factors of control with onions of this kind, are in the methods of culture followed to produce the crop.

Dry-rot of red and yellow onions is rather rare and is commonly referable to the anthracnose or Vermicularia dry-rot fungus described under white onions. The best temperatures for onion storage are about 38 to 42 degrees.

SPECIAL PART II

DISEASES OF OHIO PLANTS. ARRANGED ALPHABETICALLY ACCORDING TO HOST PLANT

ALDER

Powdery Mildews. The alder suffers from several powdery mildew fungi on the leaves (*Phyllactinia suffulta* Sacc., *Erysiphe aggregata*, (Pk.) Farl., *Microsphaera alni* (DC.) Wint.) These retard development as with other leaf coverings. Alder may also suffer from two or three leaf infecting diseases such as an anthracnose and a leaf-spot. We have as yet little data concerning other occurrences owing to the neglect of the study.

Stem Blights. From England an interesting branch parasite (*Ditopella fusispora* De Not) has been reported by Plowright. This may or may not as yet occur with us.

Root Tubercles. These root developments on the alder and some other woody plants are commonly described as *Mycorhiza*. The particular organism (*Frankia alni* Wor.) has attracted a good deal of attention from students of forest problems in Europe. Investigations of such growths upon the roots of our woody plants is very much needed at this time in Ohio.

ALFALFA--LUCERN

Anthracnose. Two new anthracnoses have been discovered attacking alfalfa; the first of these, *Colletotrichum trifolii* B&E, so far as we know occurring exclusively on plants of this family, the other, *Colletotrichum* sp., occurring only on alfalfa in northern Ohio. The first one, which we may call clover anthracnose, was discovered in Tennessee and has appeared upon alfalfa as well as red clover in the southern portion of Ohio. It is less prevalent on alfalfa than upon the red clover. Up to this time this disease has not been discovered upon either host in the northern half of the state. The second anthracnose occurred recently upon alfalfa from Sandusky and Carroll counties and has not been described. Both of these diseaseses show as a specific lesion or diseased spot on the stem or leaf-stalk in the advanced stages of attack. Following this the plants wilt or die and are discovered in this way. The disease is too new with us to measure its injuries directly. To the writer it appears less serious than the dodders or the root-rot troubles.

Bacterial Blight (Yellowing). A bacterial blight of alfalfa, of which the causal organism has not been definitely determined, has been reported from Colorado where it appears to be spreading. In 1907 and to a still greater extent in 1908, there was much complaint of general yellowing of leaves of second crop alfalfa in Ohio and adjoining states, even extending to North Carolina. The symptoms were general yellowing of this crop. With brighter, drier weather later the next succeeding crop was of normal color. Bacteria have been found by the Assistant Botanist in connection with this trouble in specimens from eight localities and from four different counties in Ohio during 1908 and 1909.

Downy Mildew. The downy mildew fungus (*Peronospora trifoliorum* D'By) has occurred in Colorado, and is very liable to occur in our state. No suggestions can yet be made as to its prevention

Leaf-Spot Fungus. This forage plant is grown in parts of Ohio. It is attacked by the leaf-spot fungus (*Pseudopeziz medicaginis* (Lib.) Sacc.) which is found upon both leaves and stem. The small dark spots produced by it are easily seen. In

attempts to produce alfalfa seed at this Station, the fungus has stripped the leaves and seed capsules before maturity. It is very likely to prevent success in growing this seed in Ohio, though it is much less injurious to the forage crop proper because of cutting at short intervals.

Root-Rot. The same parasitic fungus (*Fusarium roseum* Lk.=*Gibberella Saubinetii* (Mont.) Sacc.) which attacks wheat in the form of scab and also red clover, has been found killing out alfalfa at Wooster (See Bulletin 203). This fungus may survive in stubble fields where wheat and oats have been grown. It readily kills off the young seedlings of alfalfa and if the soil is not fully prepared for alfalfa seedings, the root-rot may extend its work and further destroy the stand. At present nothing better is known than adequate dressings of lime, preferably raw limestone, for areas to be seeded, together with their proper enrichment. At this time warning is given as to the possible seriousness of this trouble in the future. While not specifically noted in America another root-rot fungus somewhat known on other crops (*Rhizoctonia*) has also been reported upon alfalfa from France. Another root-rot fungus (*Ozonium omnivorum* Shear) well known upon cotton, also attacks alfalfa in the southwest. I believe this is not known to occur in Ohio.

Rust. Alfalfa suffers from a rust fungus (*Uromyces striatus* Schroet) and while it may scarcely have appeared in Ohio, it is almost certain to do so in time. Like the similar leaf diseases of red clover, it may have rather small economic interest.

APPLE

Bitter-Rot or Anthracnose. In recent years this fungus (*Glomerella rufomaculans* (Berk.) Sp. and Von Schr.) has been investigated and its survival in the mummy fruits and cankered branches proved. (Bulletin 40 Virginia Experiment Station; Bulletin 77, Illinois Experiment Station; Bulletin 40, Bureau of Plant Industry). This bitter-rot is also a ripe-rot, in common with other anthracnoses. For Ohio certain varieties are the chief sufferers; one of these is the Bentley Sweet grown in Belmont county, another is the Rambo. The disease develops in the later season and it seriously impairs both the eating and keeping qualities. For its control the destruction of mummy fruits and attention to branch cankers are necessary in addition to the application of sprays. Since we know the life history of the fungus better it has been possible to control the bitter-rot successfully under orchard conditions as the annual sources of infection in mummy fruits and cankers have been mastered. In this late spraying soluble sprays are used toward the end as with the black-rot of the grape.

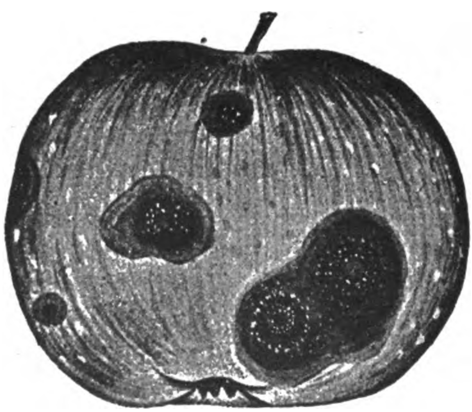

Fig. 29. An apple attacked by bitter-rot. A regular curved outline of the spores will be observed, the conidia of the fungus developing in concentric forms under suitable conditions. After Alwood.

Black-Rot. The black-rot also at times called brown-rot, is apparently more common in the orchards toward the southern portion of the state. The writer has found it a serious matter to control the black-rot fungus (*Sphaeropsis malorum*

Pk.,) which attacks both fruit and branches and is a bar to successful maturity of Northern Spy, Smith's Cider and some other varieties at certain times. It also invades storage apples and this rot is the most universal one in ordinary cellar storage. With varieties adapted to climatic conditions, methods of handling by sprays and destruction of cankers and mummy fruits should prove as effective as with bitter-rot. Unfortunately the varieties which most commonly suffer from black-rot are those growing beyond their safe range of conditions.

Brown-Rot. There is a rarer rot fungus (*Sclerotinia* (*Monilia*) *fructigena* (Pers.) Schrt.) than that of black-rot, which also attacks the apple in some parts of the United States. For our region it is little known on the apple and probably less important than either of the preceding.

Brown Spot or Dry-Rot of Baldwin. Very frequent complaint is made of small sunken spots in fine specimens of Baldwin and some other varieties. Internally these sunken spots are dry and somewhat bitter, leading to general breakdown of the apple. These spots have been referred to a particular fungus, (*Phyllachora pomigena* (Schw.) Sacc.,) but the case is not proved. This internal brown spotting also occurs in Northern Spy and in Fameuse, and we hear complaint of losses from it. The causes of the internal spotting are probably the same in all cases and must in part be regarded as physiological breakdown. New Hampshire Experiment Station (Bulletin 45) succeeded in controlling the form of this dry-rot on Baldwin by the use of Bordeaux mixture. Some irregularity in results from spraying for it have been recorded elsewhere.

Canker. These diseased conditions upon branches may occur in the propagation of bitter-rot, but are more commonly referable to the black-rot fungus, (*Sphaeropsis malorum* Pk.,) or to the blight bacterium (*Bacillus amylovorus* (Burr.) De Toni (See Bul. 163, N. Y. Experiment Station and Bulletin 235, Cornell Experiment Station) although other fungi are common in Europe as the cause of canker. Among these are species of nectria. Probably the canker due to the black-rot fungus must contest with that due to the blight bacterium for first place in Ohio, and its control is interwoven with the control of the black-rot on fruit. Canker-like dying of the external bark may, and sometimes does, occur without immediate penetration to the inner bark layer or injury to the branch. All these cankerous developments are, however, a source of danger and call for continuous watchfulness. The conditions of the fungus attacks are those of possible rifts in the outer bark followed by the localizing of the fungus development. Those for the blight canker are more extended and include blossom spurs. (See twig blight and pear blight). It seems probable also that the power of resisting attack varies with the vigor of the branches. Up to this time our remedies have been largely

Fig. 29. Apple branches attacked by canker.

the general ones of germicide sprays with addition of scraping off loosened bark where possible; for this purpose a dull tool is preferable. Some forms which might be called canker on young trunks and on older branches are in fact forms of winter injury from freezing. Types of branch cankers are somewhat variable, but they are all matters calling for close attention.

Collar-Rot. (See Sun-Scald).

Coryneum or Orange Leaf-spot. During 1908 and 1909 specimens of an orange leaf-spot have been received, and a severe case of defoliation of apple trees in town was reported from Stark county. This leaf-spot is a central, erumpent pustule with an immediate border of orange yellow: this yellow area shades off into dark color toward the green tissue. Hartley has reported, upon investigations of the fungus in this case, *Coryneum follicolum*, that it is not actively parasitic. Possibly we have this fungus following something else, after the manner that another fungus follows the black-rot leaf-spot described below. (See also rust of apple).

Crown Gall. This disease is especially a nursery trouble of apple and shows its effects by enlargements near the crown or upon other portions of the stem or root. It is quite probably due to the same organism (*Bacterium tumefaciens* Erw Sm & Towns) as the olive knot or some other crown gall troubles. This is decidedly an infectious disease which probably calls for inspection of nursery stock, and for great care to provide against diseased trees. Cure of infected plants has not been secured. There is great danger in endeavoring to grow nursery stock upon land which was once infected with the organism.

Edema. An Edema or swelling of apple twigs has been described by Atkinson from New York (Cornell Station, Bulletin 61). This on closely trimmed trees on over fertile soil.

Fly-speck Fungus (*Leptothyrium pomi* (Mont. & Fr.) Sacc.) This obvious fungus disease in ordinary seasons appears chiefly upon apples grown in low, moist situations. Peck's Pleasant, Rhode Island Greening, Rome Beauty and several other varieties have been noted as affected by the Sooty Fly-speck troubles which may be identical as to cause. During wet seasons, like that of 1896 and 1909, a few susceptible varieties are liable to be spotted by this parasite whatever be the location of the trees. Aside from selecting high, sunny situations for the apple orchard, spraying with Bordeax mixture will prevent this spot. (See Sooty Fungus)

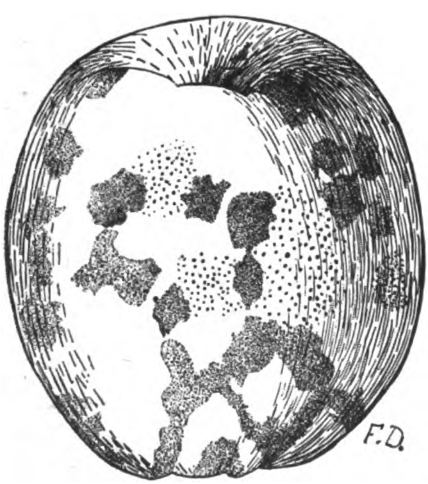

Fig. 30. An apple attacked by the Fly-speck fungus. The sooty fungus is also abundant on specimen as is usually the case.

Fruit Blotch. Fruit blotch is a recently described fungus (*Phyllosticta solitaria*, E.&E.) which causes a serious spotting of fruit in a number of ways as described in bulletins of the Illinois and West Virginia Experiment Stations, so that we may expect it to give trouble in Ohio. As indicated the fruit is attacked by this spotting and in addition the fungus produces small cankers on twigs. Scott has recently shown that it will be fully controlled by three or four sprayings with Standard Bordeaux mixture. (See Bulletin Bureau of Plant Industry).

Leaf-spot or Frog-eye. There is a common leaf-spot disease of apple trees in which the dead spots show the presence of pycnidia. This trouble is really due to the black-rot fungus (*Sphaeropsis malorum* Pk) but at times another fungus, (*Coniothyrium pirini* Sacc.), comes in afterwards. In the later season the second type develops in concentric areas to which the common name of "Frog Eye" has been given. Yet other forms of leaf-spot due to spray injuries also occur, but are easily distinguishable from the two first named. It has been shown that control of the black-rot fungus keeps the leaf-spot in hand, but early treatments should be made.

Mold. A blue mold is very commonly associated with soft rot of apples in storage. The fungus (*Penicillium glaucum* Lk.) is a very common one and may be regarded as associated with the presence of decay or bruising, not as a first cause of rot.

Mildew. The powdery mildew (*Sphaerotheca mali* (Duby) Burr.) often occurs upon nursery growths of the apple and occaionally upon rather thrifty growing young trees. The dense felt-like covering of the fungus is usually very apparent and the spreading of the fungus upon the foliage is sometimes noticeable. Spraying with fungicides usually keeps the trouble in check.

Rust. The bright orange growths of this rust fungus (*Gymnosporangium macropus* Lk., etc., I) are occasionally found on cultivated apple leaves as well as on leaves of wild thorn apples, especially where these are within reach of the cedar trees which bear the cedar apples. In 1909 the rust attacked apple fruits in Ohio and Nebraska. These so-called cedar apples are no more than the development of the rust fungus from which the spores are spread to the apple, Crataegus, etc. A remedy in indicated by this statement, viz., get rid of cedar trees.

Root-Rot. Serious root-rot troubles have been reported to us from Missouri, Arkansas and Oklahoma where orchard plantings have been made quite soon following the clearing of scrub oak, etc. Similar cases have been studied in Ohio where plantings were made soon after the removal of the timber, especially of oaks. One is usually able to identfy the rhizomorphs of the root-rot fungus, (*Agaricus melleus* L. (*Armillaria mellia*) and the characters by the occurrence upon orchard trees and also the original growth is usually quite clear. Any inadequacy of drainage is very serious in connection with root-rot. (See root-rot of peach, etc.). More recently Von Schrenck has identified another fungus (*Thelephora galactinia* Fr.) with a form of root-rot which shows no superficial symptoms until after the tree is dead; it then shows the orange, leathery sheets.

Scab. Apple scab fungus (*Venturia inequalis* Aderh, *Fusicladium dendriticum* (Wallr.) Fuckl.) is a common source of large losses in Ohio apple orchards. It attacks first the leaves and afterwards the young fruit, causing it to drop. Aside from injuring the salability of the crop obtained and reducing the vigor of the tree by reason of its attacks on the foliage, *scab may prevent a crop altogether because of this dropping of the young apples.* The Ohio Station was in the van of progress in studying this disease, and the work has been steadily followed (Bulletin Vol. IV, No. 9, (1891) B. 79, (1897) B. 111, (1899). Full details may be found in the various bulletins given. Apple scab develops when moisture is abundant during the early months of she season, and low temperatures are usually prevalent at such times. The dropping of apples often attributed to lack of pollination seems more often to be ascribed to the work of scab. All varieties are attacked by scab but some suffer more than others.

The profit from spraying for scab on the apple (including apple worms) has generally been large, because of saving the amount of crop and enhancing its market value at the same time, as well as increasing the number of crops. In this way the crops of a single orchard have been sold for a gain of about $1000 on an expenditure of $125 to $150. At the Station this gain has amounted to $5.00 per tree (B. 111). The best fungicide for this purpose is dilute Bordeaux mixture, or Bordeaux I of the spray calendar, containing 4 pounds of sulfate of copper and 4 pounds of quicklime to 50 gallons of mixture with water, or Bordeaux mixture and Iron Sticker consisting of 2 pounds of copper sulfate, and 2 or 3 pounds of iron sulfate in 50 gallons of water. The Bordeaux mixture and Iron Sticker has given better results in a rainy season like 1909. The first spraying should be made just before the blossoms open, and upon the young leaves, and the second after the blossoms drop, with additions of arsenites in the second and in a possible fourth spraying as stated in the spray calendar.

FIG. 31. Young apples attacked by the scab fungus (*Venturia inequalis* Aderh).

Scurf. The branch scurf fungus (*Phyllosticta prunicola* Sacc.) is believed to occur in Ohio. This causes roughening of the bark, but no statements can now be made as to its possible seriousness.

Sooty Fungus. The sooty fungus (*Phyllachora pomigena* Schw.) is often associated with the fly-speck fungus, previously described, and is the more unsightly trouble of the two. In most seasons the fruit in low situations is

liable to be rendered unsightly and unsalable by the spots which are illustrated in Fig. 32. In seasons like that of 1909 the disease may appear on unsprayed trees in practically all situations. It was found in comparative tests of Bordeaux mixtures and self-boiled lime-sulfur for apple scab and other fungi, at the Carpenter test farm, that the sooty fungus appeared on the fruit on the lime-sulfur trees. It is thought by several that this fungus spreads upon the fruit after it is stored and at whatever time it appears it renders apples dull, unsightly and unsalable. Bordeaux mixture or its modifications may be relied upon to hold the fungus in check. One spraying at the time the apples are the size ot hickory nuts may prevent nearly all of the injury. Upon varieties like Maiden's Blush, Grimes and Belmont the spraying should be done a little earlier than just stated. The demonstrations by the Station all over the state, show clearly what improvement the spraying makes in the apples where this trouble prevails.

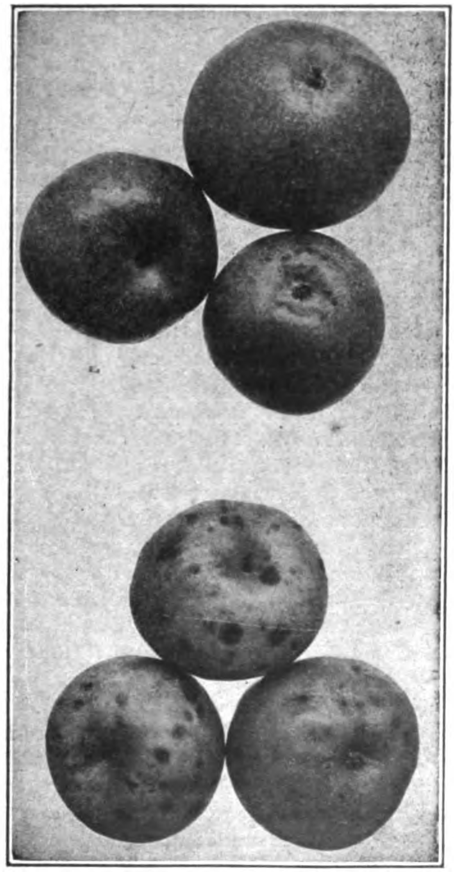

Fig. 32. Apples spotted by sooty fungus. The apples shown above were sprayed with Bordeaux mixture followed by two sprays of Bordeaux and Iron Sticker. The apples shown below were sprayed first with Bordeaux mixture and this was followed by two sprays of self-boiled lime-sulfur. In neither case was the scab entirely prevented. The lime-sulfur spray was not strong enough to keep off late attacks of sooty fungus. From a photograph by T. F. Manns.

Sun-Scald, Collar-Rot. There is frequent complaint of the dying of the trunk of both younger and older apple trees wherein there appears to be associated the exposure to sun and the death of the bark of the trunk upon younger orchard trees. The freezing injury has been carefully worked out in recent years and is discussed under winter injuries, with several varieties of apples, notably the Grimes and King this trouble is so serious over much of Ohio as to reduce the growth of these sorts; while Murrill has suggested a connection between a fleshy fungus and this dying of the trunks of the King the connection has not been proved. The injuries which occur on the south and southwest exposures of the trunk have probably a direct connection with the danger from freezing injuries. Some apparent sun-scald is more probably due to the bacterium of pear blight as has been recently proved by cultures from young trees by Waite. With Grimes and other varieties susceptible to collar-rot caused by the bacterium of pear blight the only true relief is found by top working on some vigorous sort such as Baldwin, Gano, and like varieties. In the case of true

sun-scald the effect of freezing is to form an ice layer and thus separate the bark or in the case of many water gorged cells to kill the sap layer. For further discussion in this line see winter injury.

Storage Rots. These rots of the apple are extremely various since apples infected before storage are liable to develop during storage the forms of rot due to that infection. Even bitter-rot may not be overlooked in this way and much more commonly still, black-rot and the rots which develop from the gradual invasion of molds. It is found, futhermore, that bruises upon the apple or any tendency to sun scald phenomona give dead tissues in which various saprophytic organisms that normally hasten decay will do their work with rapidity. It is understood, of course, that the temperatures of storage will regulate or control more or less perfectly the rate of this development. Storage scalding of apples is much worse in some varieties, notably in York Imperial than in the normal toughened skin types. At present one can only suggest the rejection of those sorts susceptible to scald for cold storage keeping.

Twig-Blight. This disease of the apple, caused by the bacterium of pear blight (*Bacillus amylovorus* Burr.), is often very prevalent. The microbe enters through the blossoms, being propagated in the nectar after infection by insect visitation. It destroys the blossoms as well as small twigs of the tree. Beyond the injuries just noted this microbe may gain entrance through the bark. (See sun-scald). The twig injury is not very great from this cause on the apple, though the small dead twigs are unsightly. The prevention will lie in the destruction of all the blighted parts on apple, crabapple, pear and quince trees in the vicinity. For fuller discussion see pear blight. In substance, this treatment consists in cutting out all blighted portions in fall and early winter and burning them to kill the resting forms of the microbe. It seems further that well timed, early spring spray treatments on pear, etc., will cover up or destroy spores of the blight. (See Circular 87).

Water Core. With the so-called Russian apples and occasionally with other varieties as Yellow Transparent and Early Harvest, there are water core conditions, at times, which may result in subsequent rotting. No explanation is here offered as to cause for the condition.

Winter Injury (also called Sun-Scald). As previously mentioned there are a number of evidences of injury which involve the trunks of apple trees of all sizes; they are many times due to freezing injury; while this name winter injury appears at the beginning of the paragraph and while the name sun-scald has been applied for a long time to similar conditions, the injuries are directly due to freezing, sometimes occuring in winter and sometimes, as in October 1906, due to premature low temperatures. A conspicuous case occurred in the fall and winter of 1906-7, more fully described in the bulletin devoted to these injuries (Bulletin 192). At that time as in other cases of injury from freezing, the low temperatures accurred when the trees were gorged with water (sap). In the fall of 1906 we had very heavy rainfall with low temperatures so that there was stimulus to excessive water absorption and no tendency to hasten ripening of tissues through water loss and reduced water content such as occur in dry autumn periods. The losses of young trees set one to three years, were very large in the winter of 1906; indeed, in some cases there was practically a total loss as on slow growing varieties, notably the Rome Beauty in the Station plantation at Carpenter. In general at that time the typical late variety of the northern part of the state, Baldwin, and of the southern portion, Rome Beauty and the Hubbardson were most seriously injured. It is evident that where we have such excessive water supply in the inner bark and in the process of freezing, a layer of ice crystals

is formed. There is great danger of separation of the bark layer from the wood at that time as at others. The sun exposed side seemed to have suffered worse by reason of the more extreme temperature changes which were incited on these exposures. It is evident that warm periods in winter are a source of danger when followed by low temperatures.

Fig. 33. Jonathan tree, 4 years old, Southeastern test farm, Carpenter, in cultivated portion. Tree of vigorous previous growth with small lesion near base of trunk caused by freezing and sprouts from below. Photographed July 20, 1908. From Bulletin 192.

Upon very large trunks near the base, as on Grimes and some others, this may be the real explanation of frequent sunscald or basal injuries. Wherever such an injury begins there is risk of the intrusion of wound fungi with all the consequences which follow their entrance. The handling of winter injuries must so far as prevention goes precede the conditions which cause it. Where possible the prevention of excessive late growth is desirable. In cases of orchard trees it may be that mulches of coarse litter, especially, will prove serviceable. It may be added that this injury to woody growths is a less developed phase of the killing back of herbaceous plants by the premature frosts.

Another phase still is the killing back of branches at the tips of woody growth which are not strictly hardy in our climate. In the case of our Japanese plum and of some ornamental shrubs, this is a frequent phenomenon and its cause is to be sought in the same factors above described. Growth being protracted late in the season, these water gorged terminal twigs are killed by the subsequent winter freezing whenever this is severe.

APRICOT

The apricot is rarely planted though occasionally is set in our Lake Districts. The chief difficulties there have been the tendency to kill back in winter. Apricot foliage in addition is liable to be attacked by the similar leaf parasites of peach and plum.

ASH

Trunk Rots. The ash as a forest and shade tree is a vigorous grower, but it is often marked by the attacks of timber decays where these enter through wounds or by means of the bases of dead branches. We have urgent need for more knowledge of these wound parasites.

Leaf-Spots and Rust. I may also state that the foliage of the ash is attacked by rust (*Puccinia fraxinata* (Lk.) Arth.) but in the present state of our knowledge we are unable to apply effective remedies. This rust, as in the case of other rusts, shows by the presence of its reddish or brown colored spore masses. Of leaf-spot fungi there are a number which call for careful study.

ASPARAGUS

Anthracnose. An anthracnose fungus of asparagus (*Colletotrichum* sp.) is known in New Jersey but has not been frequent, if present, in Ohio.

Rust. In the east and in Europe the rust of asparagus (*Puccinia Asparagi* DC.) proves to be destructive, and it has finally spread over Ohio.

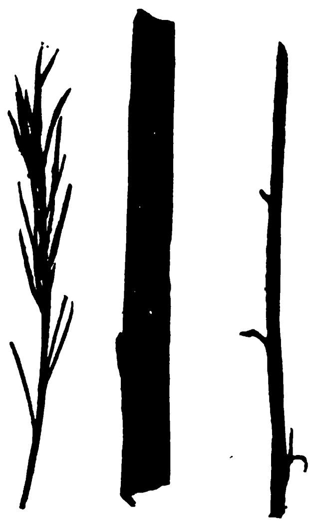

Fig. 34. Asparagus attacked by rust. The rust causes elongated development of the fungus, both upon the stems and leaves of the plant.

The rust causes appearance of unusually early maturing of the plants. Closely examined the rusted plants show blister-like spots on skin of the stem, and underneath these ruptures there is brown color due to the spores. The rust also assumes another form, the cluster-cup stage, which may be found in early spring with different color on volunteer plants; indeed the aecidial, or cluster-cup, uredo and teleutospore stages succeed each other on the stem. The usual recommendations are to burn the rusted bushes in autumn and to spray with Bordeaux mixture; this latter "reduces the amount of rust about one quarter." (N. J., B. 129). The Leopard spot of asparagus stems is apparently not infrequent, and the anthracnose of asparagus, which produces very small specks upon the stem, may also be expected, yet neither of these compares with the rust in destructiveness, nor does the rust of any other plant appear to surpass this in its ravages. The Palmetto variety is reported less susceptible to rust than any other sort.

AZALEA

Leaf-Spots. This plant is grown as an ornamental plant and whether in hothouses or in protected planting out doors, is liable to injuries from leaf diseases. One of these is a leaf-spot fungus (*Septoria azaleae*). It is also liable to attack by a "bladders" fungus upon the young parts.

BARBERRY

Rust. The rust upon the barberry bush (*Aecidium Berberidis* Gmel.) is but a form or stage, the aecidial or cluster cups, of the wheat rust (*Puccinia graminis P. rubigo-vera* etc.). The increase of virulence in the rust of wheat and rye, when grown near barberry bushes, was long noted before the demonstrated

alternation of the fungus from the barberry to the wheat was proved in our century by DeBary. The barberry hedge is objected to, at times, by adjacent wheat growers, although we continue to suffer from the ravages of wheat rust many miles from any barberry bushes. In the absence of barberry the rust survives without it.

BARLEY

Rust. In the west and northwest there are two forms of rust; leaf rust (*Puccinia simplex* (Koern.) Erikss. and Henn.) and stem rust (*Puccinia graminis* Pers.). These rusts, like those of the other cereals, have not yet been mastered or controlled.

Scab. Barley is attacked by scab (*Fusarium roseum* Lk.) in a manner similar to that which occurs on wheat and rye. That the scab fungus is the same for all grains has been shown by recent work of this department. (See Bulletin 203).

Seed treatment for the loose spores and seed recleaning to get out the shrunken and scab infested kernels ought to give favorable results. (See wheat scab).

Smuts. The covered barley smut (*Ustilago hordei* (Pers) Kell. & Sw.) as well as the naked barley smut (*Ustilago nuda* (Jens.) Kell. & Sw.) both occur in Ohio, although barley is grown less extensively with us than in the west and northwest. In the covered barley smut, the smutted heads more commonly remain enclosed by the upper leaf sheath and a membrane holds the smut masses, while the spores are exposed and freely scattered in the naked barley smut.

The modified hot water treatment for loose smut of wheat has been found effective upon the barley smuts. See Farmers' Bulletin No. 75, Yearbook U. S. D. A., 1894. Spray Calendar, Bulletin 199.

BEAN

Anthracnose. The anthracnose of the bean causes unsightly spotting of both pods and growing organs and is referred to the anthracnose fungus (*Colletotrichum Lagenarium* (Pass.) Hals.). This species is also regarded as the same one that attacks curcurbits, including cucumbers, watermelons, muskmelons and gourds. The spotting of the bean pods is looked upon, too commonly, as a natural phenomenon. Measures looking to its prevention have not found ready application by growers. That fungicides are effective in reducing it we have reliable testimony (N. J. Exp. Sta. B. 108). The recommended treatment begins by soaking the seed 1 to 2 hours in ammoniacal copper carbonate, 1 ounce of copper carbonate to 1½ gallons of water. Bordeaux mixture is to be sprayed upon 2 and 3 inch plants, followed by the same 10 days later, and again repeated after blossoming of plant. The great thing to remember is that this is a seed infecting disease. We must grow disease-free seed. (See Pea).

Bacterial Spot. A bacterial blight has been reported from New York (N. Y. Exp. Sta. B. 181) and New Jersey (Exp. Sta. Rept. 1892) which promises more or less injury. In this malady the diseased parts, leaves, pods, etc., show characteristic, often watery spots. It is less prevalent on fresh land. The organism (*Bacterium phaseoli* Erw. Sw.) is widespread.

Downy Mildew. This fungus (*Phytophthora Phaseoli* Thaxter), so far as known at present, has not been found in Ohio, though occurring to a destructive extent in the east, and liable to occur in our vegetable gardens. Experiments have shown that it is controlled by spraying with Bordeaux mixture.

(Conn. Exp. Sta. R. 1897, Pt. III). In this instance, as with the downy mildew of cucumber, it is probable that August 1 is sufficiently early to begin the application of the fungicides.

Powdery Mildew. Powdery mildew of the bean is due to the same fungus as the powdery mildew of pea, for which see pea.

Rust. This fungus (*Uromyces appendiculatus* (P.) Lev.) is often observed to produce reddish brown spore masses upon both surfaces of the leaves of beans. It is perhaps rather more variable in occurrence, and certainly less injurious in the past than bean anthracnose. It has been quite common in Ohio. Beyond burning diseased refuse we are not prepared to suggest remedial or preventive measures.

Stem-Rot. The root-rot fungus (*Rhizoctonia*) attacks the bean root and stem and at times spots the pods in the south.

BEECH

Anthracnose. The anthracnose fungus (*Gloesporium Fagi* (Rob.) of beech attacks the leaves, but is not so serious as many of the other anthracnoses.

Leaf Diseases. While the beech is not largely planted, it is nevertheless a useful shade tree. The leaves are often attacked by two or three mildews (*Microsphaera erineophila* Pk. & M. *penicillata* (Wallr.), also *Phyllactinia suffulta*), which, however, rarely gives serious injury to foliage. In Europe the beech is attacked by a rust fungus (*Melampsora Fagi*); the leaves are also attacked by a leaf-spot species of Phyllosticta.

BIRCH

Anthracnose. The anthracnose fungus of birch (*Gloeosporium Betularum*, E&M) attacks the leaves of our American birches while other anthracnoses are known on the European species. Our knowledge of the injury is very limited.

Mildews. The downy mildews of beech and alder in part occur upon the birches.

Wound Fungi. Characteristic fleshy fungi invade pruning or other wounds in the birch and are to be guarded against as with other woody growths.

BEET

Leaf-Spot. The garden beet is quite liable to the attacks of the leaf-spot fungus (*Cercospora beticola* Sacc.) which causes serious impairment of leaf action and premature dropping of the foliage. Other changes are likely to follow those stated. This trouble may be controlled by the use of Bordeaux mixture at fortnightly intervals. (B. 199). The leaves of beets are also attacked by a white mold (*Cystopus Bliti* (Biv.) Lev.) although this latter fungus is less frequent and less ruinous than leaf-spot. The same fungicide may be used if required. See "sugar beet" for other diseases.

Scab. The scab troubles on the beet are similar to those on the potato and are referred to the same fungus. This trouble is likely to follow where beets follow in soil that has been diseased with either beets or potatoes.

Root-Rot. (See sugar beet).

BEGONIA. (See Pelargonium).

Nematodes. These minute worm parasites attack the roots and also the leaves of cultivated begonias (Ohio Exp. Sta. B. 73; N. J. Exp. Sta. Rept. 1894). For the commoner root injury avoidance is to be sought in the preparation of the earth.

Root-Rot. The root-rot fungus of violets and tobacco *Thielavia basicola* Zopf.) was found attacking the roots of begonia which suffered from nematodes. Its general occurrence since the discovery upon tobacco and catalpa show that it is capable of serious injury to the roots of these cultivated plants.

BLACKBRRRY

Anthracnose. The anthracnoses of blackberry and raspberry (*Colletotrichum venetum* Speg.) are idential and are described under the raspberry.

Leaf-Spot. This disease is also common to the blackberry and the raspberry, although the latter is less commonly attacked. This fungus (*Septoria Rubi* West) is conspicuous upon the wild growth and upon the trailing dewberries; it produces, usually, small, light-gray spots in the leaves and yields to treatment with the standard fungicides. (See Ohio Exp. Sta. B. IV, 6, and B. 79).

Crown Gall. Is apparently of a similar contagious nature to that of the raspberry.It is of like appearance, though the galls at the crown of the plant are often larger. A plant once attacked is incurable, and offshoots from it appear to be generally affected, thus calling for immediate digging and burning of all the diseased canes and the abandonment of propagation from such plantations. (See raspberry crown gall).

Red Rust or Bramble Rust (*Caeoma nitens* Schw.) is a well known disease of the wild and cultivated blackberries, which also attack raspberries. It causes the affected leaves to turn first yellowish in color, remain erect in position, and finally to become bright red with an abundant coating of the spores of the rust fungus. These spores are readily scattered and may thus affect previously healthy plants. The threads of the rust fungus (mycelium) live year after year in the affected plants. For this reason the only remedy is to dig and burn all members of the rusted stools. (See Bulletin 79).

Root Diseases. Recent examinations of blackberry plantations show root diseases of undetermined cause. The affected roots show brown spots as if parasitized and the growth is seriously curtailed. Recent conditions in blackberry plantations indicate root parasites since sections of the roots become discolored and the growth of the canes is checked. These have not been sufficiently investigated for exact determination at this time.

BLUE-GRASS

Anthracnose. In the summer of 1908 the anthracnose fungus of wheat, rye, oats and other grasses (*Colletotrichum cereale* Manns) was discovered on blue-grass in Ohio. This shows as black spots on the stems and basal sheaths, and will evidently survive on this pasture grass. The injury is greater upon wheat, rye, oats and clover, under which illustrations are given, than upon blue-grass.

Bacterial Blight of Head. In a recent bulletin from this department (No. 210), Manns has described the organisms of blade blight in oats and has reported a head blight in blue-grass and timothy caused by them. In this case the bacteria appears to enter the upper sheath and cause a lesion above the upper joint. This ends in the death and the drying up of the heads.

Powdery Mildew. The foliage of the blue-grass is attacked by the conidial stage of the wheat mildew (*Erysiphe graminis* DC). This fungus gives little evidence of injury, though its presence is certainly *not* beneficial and the perithecia of the parasite are not common on this host.

Rust. Blue-grass is likewise attacked by a rust (*Puccinia graminis*) which is general on grasses.

Smuts. A smut fungus (*Ustilago striaeformis* West.) attacks the blades of blue-grass though it is possibly not often very injurious.

BROOM-CORN

Smuts. Of these there are two, head smut (*Ustilago Reiliana* Kuhn.) and grain smut (*Cintractia Sorghi-vulgaris* (Tul.) Clinton), the latter of which is prevented by treating seed for 15 minutes in hot water at 135 degrees F. and drying

for planting as for oats. The same smuts attack sorghum and are very likely to occur in foreign seed. (See Kansas Experiment Station Bulletin 23; Ills., Bulletin 47).

BUCKWHEAT

Leaf-Blight. This well known plant is frequently attacked by a leaf-blight fungus (*Ramularia rufo-maculans* Pk.) which produces whitened areas on the under leaf surfaces and causes dying of these leaves. It is not known to be sufficiently destructive to warrant treatment for prevention.

Another leaf trouble referred to a fungus (*Fusicladium fagopyri*) is reported from Europe, but is not known in our climate.

CABBAGE-CAULIFLOWER

Brown- or Black-Rot is a serious disease of these two crucifers, and attacks others of the family, including turnips. It is a veritable scourge to the cabbage growers of Ohio and other states. Smith (Farmers' Bul. 68, U. S. D. A.) has published concerning it and has attributed the disease to a specific germ (*Bacterium campestre* (Pam.) Erw. Sm.). The diseased heads may be dwarfed, in portions rotted, and brown colors will appear in the woody layers of the plant, including the stem. Badly diseased heads emit a penetrating and offensive odor.

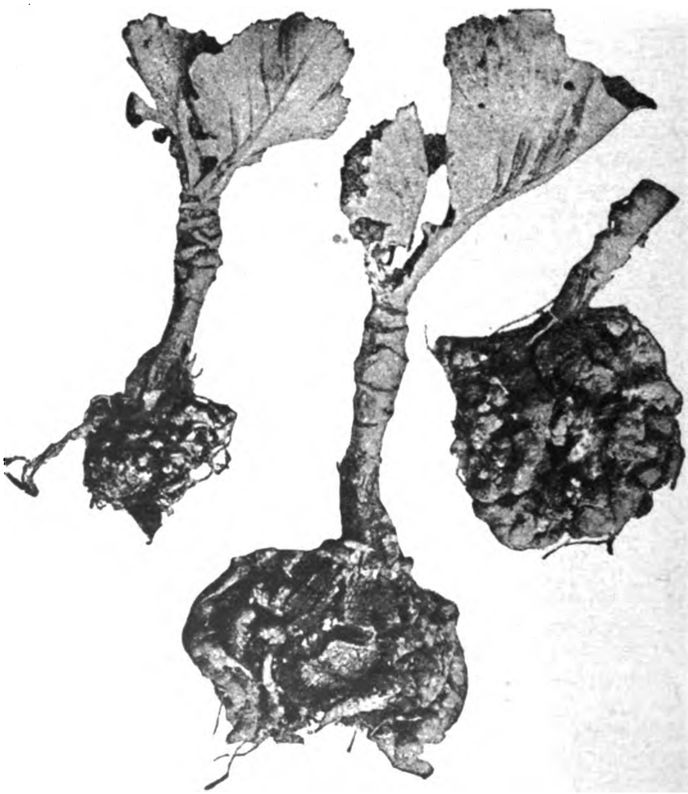

Fig. 35. Young cabbages partially affected with club-root The club-root survives in the soil and causes swellings and abnormal forms of the roots. After Halsted, Bul. 98, N. J. Exp. Sta.

The losses from the brown-rot have been very large and specific remedies cannot be stated. The author quoted sums up the subject of treatment in one word—prevention. The measures recommended are—plant on new land and only from healthy seed beds; avoid succession of the same crops; avoid stable manure and give preference to artifical fertilizers to escape possible infection through the manure. Prevent animals from cropping in diseased fields. Clean tools by scouring bright after use in infected soil. Fight the cabbage insects, since these inoculate healthy plants with the disease. Removal of badly affected plants, or newly infected leaves, at intervals, and subsequent burning or deep pitting of this refuse may aid in checking brown-rot. Destroy all mustard weeds. See page 318 for part played by water pores in the infection.

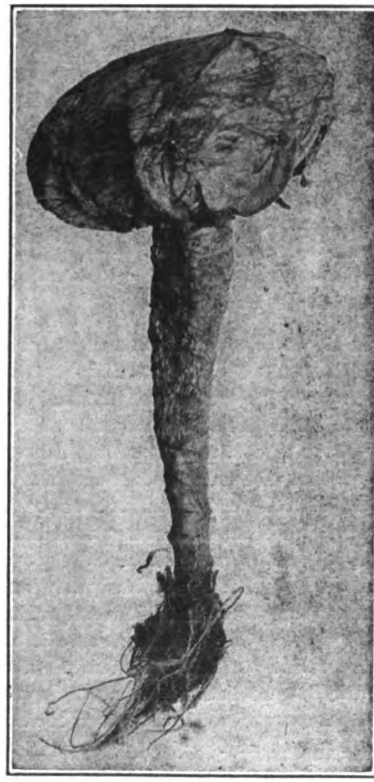

Fig. 36. Cabbage plant attacked by Fusarium wilt. This has caused the leaves to yellow and drop and the plant has produced no marketable heads. The lesion caused by wilt fungus may be observed upon the left-hand side, upper half of stem. From a photograph by T. F. Manns.

Club-Root. Club-root fungus (*Plasmodiophora Brassicae* Wor.) attacks these plants as well as the turnip, rutabaga, wild shepherd's purse, hedge-mustard and certain other plants of the mustard family. It is called finger and toe disease in England. It causes enlargement of the roots and prevents growth of normal head or root. (See figure, p. 380).

This fungus is harbored in the soil, so that if the land is once infected the disease may prove lasting. It has not yet been learned how long the trouble will survive if the soil is planted in other crops. Lands newly brought under cultivation may be infected with club-root through the wild mustard plants upon them. It would appear possible by watchfulness to avoid getting the club-root fungus into cabbage lands; the seed bed should be most carefully guarded from this trouble as from rot. It will be much cheaper to abandon the crop for some other, when the plant bed has become affected with club-root and the seedlings have enlarged or whitened roots from this disease.

In New Jersey, Halsted has investigated this trouble and has found (N. J. Exp. Sta. B. 98 and 108) that fresh stone lime, if applied at the rate of 75 to 80 bushels per acre upon freshly plowed land in spring, and worked into soil, will very greatly reduce the amount of club-root on turnips and cabbage; there is no reason to doubt that this treatment is applicable to all plants of the order attacked by club-root.

Downy Mildew (*Peronospora parasitica* DeBy.), Leaf-Blight (*Macrosporium Brassicae* Berk.) and White Rust (*Cystopus candidus* (P.) Lev.), occur upon the mustard plants, including, perhaps, all named above and some others. As yet their presence has not proved a serious drawback. If to be treated, Bordeaux mixture should be applied.

Wilt. The fusarium wilt disease earlier reported from the eastern truck districts, is now very destructive in Ohio. In 1909 it locally destroyed nearly all the crop where either infected plants were set upon fresh soil or plants were set on infected soil. It causes a yellowing and wilting of the plants sometimes with apparent stem injury. In our cabbage districts it may be this wilt is to contest with black-rot for first place in rank of injury done. The remedy lies in breeding wilt resistant strains of cabbage.

CALLA

A Root-Rot of callas has been studied by Halsted and Townsend. The disease appears to be due to bacteria (N. J. Rept. 1893). Reject rotted roots.

CARNATION

Bacteriosis of carnations has been reported upon by Arthur and Bolley (Ind. Exp. Sta. B. 59). This causes many small, brownish spots with yellowing of the leaves of the affected plants. Such are feeble in growth and deficient in return. The maintenance of best and most favorable growth conditions may often be effective in preventing this trouble; particularly sub-irrigation and war on aphides are to be recommended.

Bud-Rot. A serious rot of carnation (*Sporotrichum antrophilum* Pk.) is reported from several states and is doubtless present in Ohio.

Leaf and Calyx Mold (*Heterosporium echinulatum* (B.) Cke.) (**Fairy Ring**) of carnations is often very unsightly upon the calyces and pedicels of these flowers; it also attacks the leaves. All sorts appear to be more or less parasitized with the fungus in the houses where it prevails. Yet another spotting is produced by the carnation leaf-spot fungus (*Septori Dianthi* Desm.), which has appeared at this Station more frequently upon the Daybreak variety. It is believed that both these fungi will yield to treatment with Bordeaux mixture as per calendar. (See Bulletin 73).

Carnation Rust (*Uromyces caryophyllinus* (Schrk.) Schroet.). This rust fungus is one of the serious diseases of the carnation. There is some differerence in the liabitity of varieties to the disease, and perhaps a much larger difference in the condition of the stock plants from which cuttings are made. Assuredly this matter of "cutting stock" is of very great im portance and one admitting of selection of the very best plants. Experiments conducted at this Station in 1896 by the writer and the Station Florist (See B. 73) yielded no gain from spraying with Fowler's solution, which has been sometimes recommended. Watchfulness in the destruction of rusted parts, and in the stock for propagation, are suggested for the control of rust.

A Root- or Stem-Rot (*Rhizoctonia* and *Fusarium*) of carnations has been noted by Stewart (Bot. Gaz. XXVII, 129, 130) and occasional rotting of the flowers through the presence of a Botrytis. For the former no thoroughly effective remedy is now at hand, while general cleanliness of the house is necessary to avoid the rot fungus Botrytis. (See Lettuce Rot).

CANNA

Rust. Foliage of canna is sometimes attacked by a rust which may be identified by the characters of its fungus (*Uredo cannae*).

CANTALOUPE

See Muskmelon.

CARROT

Leaf-Spot. This spotting of carrot leaves is usually caused by the same fungus (*Cercospora Apii* Fres.) as the celery leaf-spot. Upon the carrot the trouble is not usually serious.

CEDAR

Cedar Apples or Cedar Rust. During the showers of April, May or Juue, large or small, jelly-like masses, often one inch or more across, with firmer wood-like centers, are frequent upon red cedar trees and upon similar related plants. Microscopic examinations of these jelly masses show that they contain the spores of a rust fungus (*Gymnosporangium macropus* Lk. and other species of Gymnosporangium). This fact need not startle us but for another, namely, that this is the completed or teleutospore stage of a rust which may seriously injure the leaves of the apple. The apple grower will run some risk then, in having about him diseased cedar trees. The remedy lies in the destruction of the cedar trees.

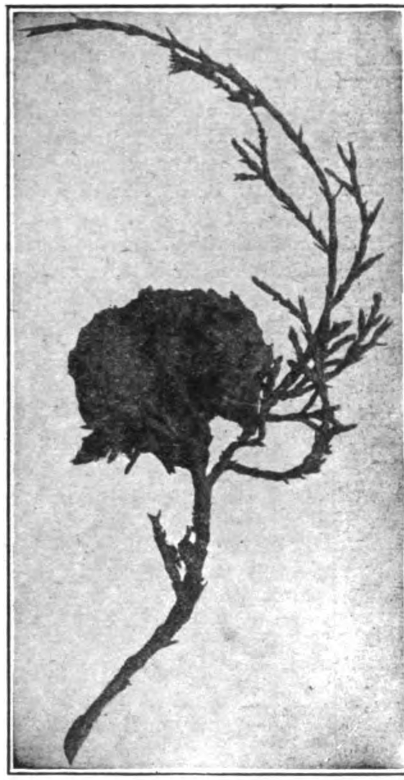

Fig. 37. Cedar apples caused by rust fungus. In May these dry looking apples send out jelly-like branches filled with spores of the rust fungus. These spores may attack leaves and fruit of apple, as well as crataegus and juneberry. (From a photograph by W. P. Beeching).

CATALPA

Leaf Blight. Leaf blight of catalpa has recently been troublesome to growers and puzzling to the Pathologist at times. The sudden blackening and dying of the leaves in early summer has been traced to frost, but other times in later summer to root-rot, which see. Frequently we have found a leaf blight fungus (*Alternaria* sp.) which developed freely upon the spotting leaves and appeared to be responsible in conjuction with some other rather unfavorable conditions for the young trees. This will probably give more trouble in the culture of the catalpa than the leaf-spot or mildew which have been known much longer and prove less serious. Early applications of Bordeaux mixture repeated at moderate intervals should check the disease.

Leaf-Spot. The leaf-spot (*Phyllosticta Catalpae* E. & M.) is quite frequent upon the leaves of catalpa. It rarely causes more than occasional spots in the leaves, the injury being in no way comparable to that caused by the catalpa midge. Fungicides should be effective against the true leaf-spot.

Mildew. The leaves of catalpa are often covered over by the powdery mildew fungi (*Microsphaera elevata* Burr., *Phyllactinia suffulta* Reb.). These mildews tend to become conspicuous by the white covering upon the leaves in later summer. While unsightly the injuries are rarely serious.

Root-Rot. Since the recent demand for seedling trees of Catalpa speciosa, some difficulties have been met with in diseased seedlings of catalpa. These seedlings are liable to be attacked in their early stages by the ordinary damping off fungi such as Rhizoctonia, Pythium and Botrytis. One interesting case of a true root-rot fungus was studied in 1908. The seedlings were being grown in land that has been used some years for truck gardening; the stand was cut down very much and in later summer some of the seedlings, then a foot or more in height, showed sudden dying and dropping of the leaves; this was found to be due to the root-rot fungus of the violet and tobacco (*Thielavia basicola* Zopf.). This must have been quite serious on the smaller seedlings. At the date of study, September, only the smaller root branches were destroyed by it and the larger ones seemed normal. The injury to these seedlings in dry weather was enough to bring about leaf collapse due to reduced water supply. If this fungus becomes very general it will involve soil treatment for such seed beds. It was too soon to determine how serious it may be upon trees of larger nursery size, although it is not greatly feared.

CELERY

Black-Root, so-called, may be found on celery plants from seed beds. In one instance such plants yielded growths which shortly run to seed and were valueless.

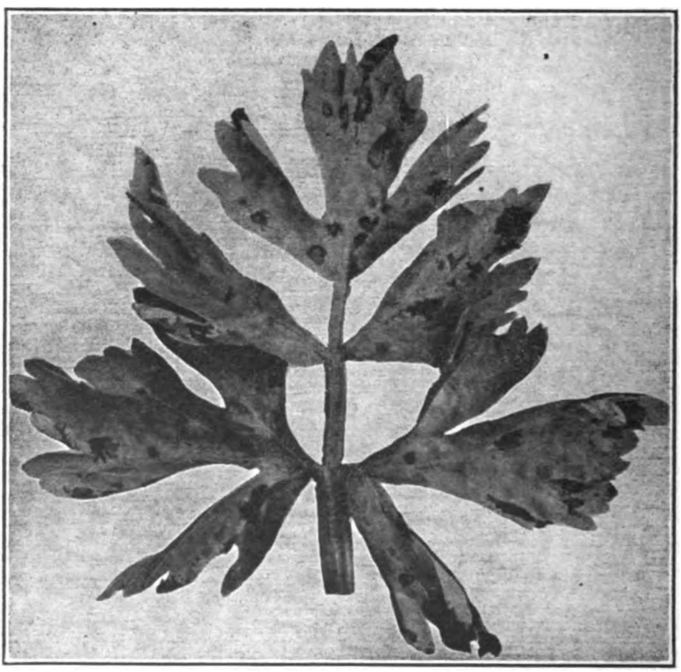

Fig. 38. Celery leaf attacked by leaf-spot. Various troubles produce similar spotting in celery leaves.

Leaf-Spot or Leaf Blight (*Cercospora Apii* Fres.) is a prevalent condition upon celery plants. This is at times attributed to the fungus above named, or others, and is also produced by other causes, as by excess of water during overflow and the like. During certain seasons the loss from the leaf-spot or leaf-blight troubles is very much greater than during others. This is clearly explained when the conditions giving rise to the leaf troubles are apparent.

But this is by no means a common fact, and in some years there is much blighting after the celery has been boarded up for blanching. Usually the fungus is discoverable in diseased areas of the leaves. The use of fungicides, such as Bordeaux mixture, is likely to prove beneficial, especially to protect the plants in the seed bed until transplanted. (See Spray Calendar). While beneficial for later applications in the field, so long as it is not clear that the fungus parasite is not the only cause of blighting or leaf spotting, all possible conditions should receive attention. Kinney (Rhode Island Exp. Sta. B. 44) has suggested that the breaking down of the celery leaves arises from the methods of culture practiced, particularly the level culture, in which the water relations of the plant are not in a natural state. He succeeded in preventing the blighting of celery by mulching with celery tops in which there was a large supply of the fungus. Mulching, especially during periods of prolonged drought, may thus prove profitable. The identification of the particular fungus occurring in the spots must, in each case, be made by the misroscope. Aside from the mulching suggested the remedies are stated in Bulletin 121.

The conditions of celery culture are yearly becoming more troublesome and are really serious.

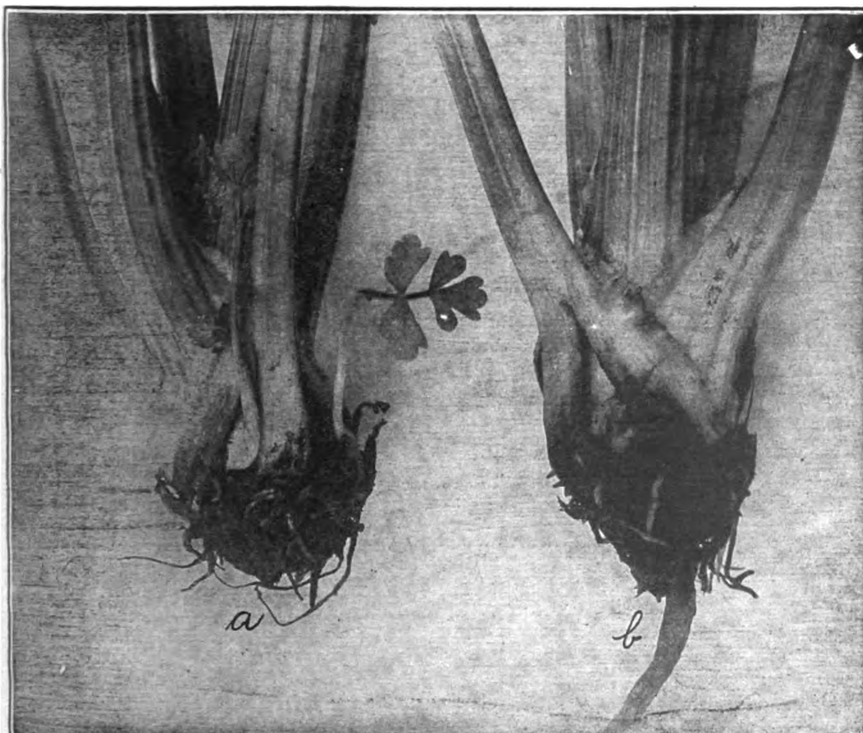

Fig. 99. Younger celery plants attacked by root-rot. These plants are kept alive by new roots, though they increase but little in size. After VanHook, Cir. No. 72.

Heart-Rot is a very destructive decay of the inner, or heart, portions of the celery plant after blanching has begun. The inner parts rot very suddenly, emit a penetrating odor and the market value of the affected celery is destroyed.

The decayed parts are teeming with motile bacteria to which this form of decay has been attributed. The heart-rot prevails too in very hot, steamy weather, but preventive measures are about all that can be recommended. It is suggested that when the boards are first put up to the celery, under such conditions as accompany the heart-rot, they should be left apart at the top and only closed up to the usual point after an interval of several days. This secures better ventilation and often prevents the disease.

Root-Rot. During a succession of wet seasons much trouble developed in the Akron district from attacks of root-rot (*Rhizoctonia*). This gave trouble at times with the seedling plants, but more seriously with the shortened development of the crop. Often the roots were nearly all rotted off. The trouble seemed to decline rapidly with drier seasons. (See Circular No. 72, Ohio Exp. Sta.).

Rust, true and false. In Europe the celery plant is attacked by one or two rust fungi (*Puccinia bullata* (Pers.) and *P. Castagnei* Thüm.) of the same class of parasitic fungi as those producing rust in wheat. These two rusts have not as yet been discovered in America, though they will doubtless in time become introduced. Celery which is banked in the earth often has the blanched stems marked by rusty spots of various sizes. These spots appear to arise from the contact of the stems with the earth, and on microscopic examination seem to be due to the fungi or bacteria, or both, that may be present in the soil. The difficulty is prevented by avoiding this method of blanching and substituting boards or close culture planting.

Bad Seed. There is scarcely a more vital question in celery growing than that of the quality of seed used. Seed that is of a bad strain though true to varietal name, may inflict losses of hundreds or thousands of dollars on large growers. Hollow celery, or that otherwise useless, according to present knowledge is very often due to the bad seed.

Fig. 40. Twig of cherry attacked by black knot. This is the summer condition when the conidia are numerous upon the surface and often give an olive color to the knot.

CHERRY

Black-Knot. This is a conspicusus disease attacking the branches of cherry and plum trees but is more frequent upon the cherry varieties of the Morello type. It is due to a parasitic fungus (*Plowrightia morbosa* Schw.). Insects, however, make harbors of the interior of the knots. The spores of the black-knot fungus are ripened during the winter and scattered in early spring, finding lodgement on the new branches or in fractures on old ones, where their growth causes the formation of a new knot. Black-knot may be prevented by spraying with Bordeaux mixture, but is more profitably controlled by carefully cutting off affected parts and burning them, making a clean sweep at least once each year and that *previous to March 1st.* This is a practicable measure and we have confidence in its efficiency.

Leaf-Spot and Mildew. The first named disease is caused by the same fungus (*Cylindrosporium Padi* Karst.) as that which we call "shot-hole fungus" on the plum, and may be successfully prevented by the use of Bordeaux mixture, except that only half the strength of mixture may be applied with safety to the foliage of the cherry. (See Calendar). The mildew is usually found chiefly upon sprouts

and young shoots. The mildew fungus (*Podospharva Oxyacanthae* (DC.) De By.) is a very interesting one. This applies especially to amateur microscopic study. If spraying is required for the mildew two applications will probably be very satisfactory.

Cherry-Rot or Brown-Rot (*Schlerotinia* (*Monilia*) *fructigena* (ers.) Schw.) affects all stone fruits, including peach, plum, apricot, etc. It is by far the most serious and baffling of cherry diseases to the commercial cherry grower. The decay of the fruit is caused by the fungus named. The conditions of the season may favor or retard the spread and development of the fungus. The threads of the fungus (mycelium) survive in the rotted fruits, which may hang on the trees unless removed. Careful removal of all rotted fruit and spraying for the fungus, as per the calendar, may be relied upon to save a part of the fruit, but judgement and attention to the details of the work are always required. It is to be understood, also, that checking the curculio is a sure means of helping to check rot.

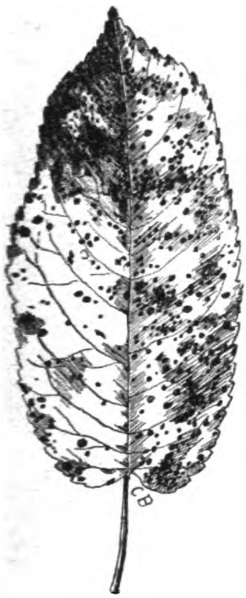

Fig. 41. Leaf of cherry attacked by leaf-spot fungus. The dead areas in cherry leaves turn dry and rarely give shot-hole effects. The same fungus occurs upon the plum. From Bulletin 79.

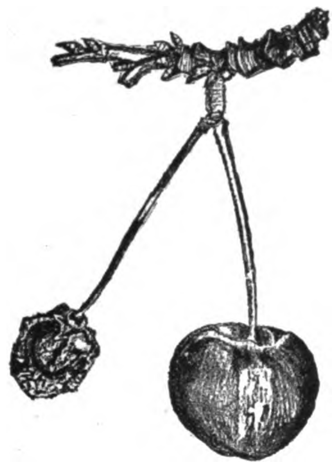

Fig. 42. Cherries, sound and rotted. The parasite in this case is the same as on other stone fruits.

CHESS

Anthracnose. The anthracnose fungus (*Colletotrichum cereale* Manns. attacks the chess as well as the cerea s in which it may grow. The disease is of interest upon chess because it may be a source of extending the development of anthracnose. (See anthracnose of oats, rye and wheat).

CHESTNUT

Anthracnose is a disfiguring spotting of chestnut leaves, about which inquiries are often made. Small, dead areas with characteristic borders are produced by this fungus (*Marsonia ochroleuca* B. & C.). Such applications of fungicides as are made for shot-hole fungus of the plum and leaf-spot of the horse chestnut, will be found useful when treatment becomes necessary on the chestnut.

Bark Disease. A serious bark disease of chestnut in the east has recently been described and has proved injurious. The fungus (*Diaporthe parasitica* Murr.) appears to enter as a wound parasite through openings in the bark. It has exterminated a part of the chestnut trees in the eastern half of Long Island and about New York City. (See Yearbook, U. S. D. A., 1907, pages 489-490, also Bulletin, Bureau of Plant Industry, No. 121, 1908). The beginnings of the

disease show on branches with smooth bark, by the presence of dead, discolored or sunken patches sometimes covered with the yellow orange or brown pustules of the fungus.

CHRYSANTHEMUM

Leaf-Spot is frequently a disfiguring disease of this plant in earlier growth. It is caused by the leaf-spot fungus (*Septoria Chrysanthemi* Cav.). Two other fungi, a Phyllostica and a Cylindrosporium, also attack the chrysanthemum. For indoor treatment copper sulfate solution of one fourth of the strength given in the spray calendar—that is one pound to 50 gallons of water—will prove available. More applications will be required, but the foliage will not be rendered so unsightly as with Bordeaux mixture which, however, may be applied in full strength.

Powdery Mildew. Powdery mildew also occurs upon chrysanthemum foliage. The fungus (*Erysiphe Cichoracearum* DC.) is usually not persistent, but calls for spraying foliage with fungicides when serious.

Ray Blight. A blight of the rays of chrysanthemum flowers due to a specific fungus (*Ascochyta chrysanthemi* Cav.) is reported from the south and is very liable to be present in Ohio.

Rust. This is found on the chrysanthemum, resembling other rusts in its development. Rusted leaves and badly rusted plants should be destroyed.

Fig. 43. This shows clover plants from fields at the Station attacked by new anthracnose fungus in 1909. This causes the leaves to droop and die; also at times the tips of the stems. From a photograph by T. F. Manns.

CLOVER

Anthracnose. Three anthracnoses occur upon clover; the more common of which is due to the same fungus (*Colletotrichum trifolii* B. & E.) as the anthracnose of alfalfa. In 1907 it attacked the clover over the southern one-third to one-half of Ohio, causing dying of the plants attacked. These show lesions of the stems and leaf stalks and may be detected in the new seedings in late summer through the dying of the leaves of these plants. It is not known how serious this may prove upon clover, nor is this one known in northern Ohio.

The second anthracnose fungus (*Gloeosporium trifolii* Peck.) has been known longer than the first and occasionally shows by killing the tops of large

clover stems in meadows. It is apparently not a serious disease, although a very interesting one to study in connection with the anthracnoses due to Colletotrichum.

The third anthracnose upon clover (*Colletotrichum cereale* Manns.) is the anthracnose of wheat, rye and oats. It was found to a limited extent attacking clover upon the Station grounds in 1909. Except in microscopic characters this anthracnose cannot be distinguished from that of Bain and Essary first mentioned above. In the microscopic characters the two are clearly distinguishable. It is quite probable that this fungus will be found over much of the state.

Black-Spot is due to a fungus (*Phyllachora trilfolii* (Pers.) Fckl.) which attacks the leaves of clover causing dead spots and dark discolorations on the under side of the leaves. As a rule these attacks come so late in the working life of the leaves that the injury is slight.

Dodders occur upon clover as well as upon the alfalfa; with it, likewise, there are two species (*Cuscuta Epithymum* Murr. and *Cuscuta arvensis* Beyr.), the seeds of which are distributed in the clover seed. In 1907-8 when the domestic supply of seed ran so low the lack was made good by importations from Europe. This has brought a large amount of dodder into the state, the most of it being the clover dodder proper. With clover seedings as with alfalfa where infestations are slight it will pay to dig up by root the infested plants and burn them for destruction of possible seeds. Dodder is a parasitic twining plant and may be easily recognized by its appearance. The seeds are illustrated in Bulletin 175.

In the handling of the new clover seedings infested with dodder, it is probably best to clip in fall to prevent ripening of the dodder seeds. The hay crop may be cut the following season without fear since the seeds will not be in condition to grow. Following the mowing of the hay crop it is probably desirable to break the clover sod after the growth is fairly well started, and before time enough has elapsed to permit ripening of the dodder seeds. In no case is it desirable to cut seed from such dodder infested fields. Dodder in clover hay is held responsible for scouring of cows and horses.

Leaf-Spot. A leaf-spot of white clover referable to an anthracnose fungus (*Ascochyta* sp.) has been described from our region although not definitely determined in Ohio. The injury which may result cannot be now stated.

Rust. The various sorts of the cultivated clover, Red, Alsike, Mammoth, etc., are attacked by a clover rust (*Uromyces Trifolii* (A. & S.) Wirt). If one will examine the small, dark spots in the clover leaves he will find a cluster of this reddish fungus beneath. This rust does not spread to other plants than clovers and is commonly regarded as more disfiguring than destructive. It is not nearly so injurious as the leaf-spot of alfalfa which is similar in appearance.

Root Nodules and Root Tubercles upon Leguminosae. Upon removal of the roots of the clover plant from the soil one finds minute enlargements which are the subject of frequent inquiry. These are nodules or tubercles as they were formerly called, caused by the messmate-living of certain nitrifying organisms, or microbes, with the clover plant. To these microbes in this communal life is due the power of withdrawing nitrogen from the atmosphere and fixing it in the the tissues of the clover plants. The same applies in general to the nodules upon plants of this order, the *Papilionaceae.* It thus follows that these nodules are the normal condition of properly nourished leguminous plants of the order *Papilionaceae*, and it likewise follows that the full value of this work of nitrogen fixing is only realized for manurial purposes when the tissues of the clover plants decay in the soil.

Stem Blight of clover has recently been studied at the Station and has been found to be due to the same fungus as that of wheat scab (*Fusarium roseum* Lk.). This fungus has been found to cause the death of seedling wheat plants and to follow harvest by attacks on clover stems. (See Bulletin 203). It appears at this time to be one of the serious forms of clover sickness. The writer looks upon it as liable to be much more serious even than anthracnose. The only present suggestion for control will apply to control of the wheat scab fungus through recleaning of seed and separation of of all scab infected kernels. It is quite likely that clover seedings made in a dry year with little grain scab will not be exposed to the same danger from this blight as those made in wet seasons when the disease is very bad in the grain. (See wheat scab).

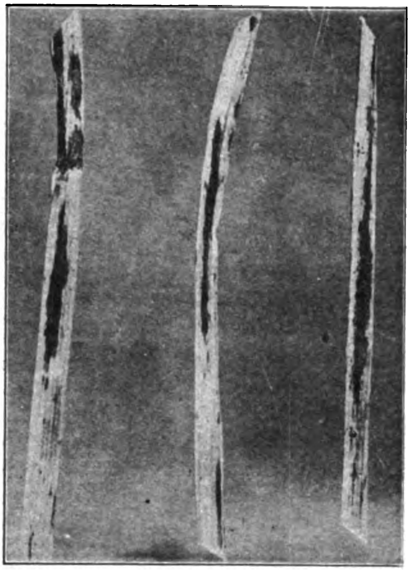

Fig. 44. Red clover stems suffering from stem sickness. The grayish spores in the lesions are those of the fungus of wheat scab. From Bulletin 203.

CORN

Bacterial Disease. This has been described and illustrated in Bulletin 6 of the Illinois Experiment Station, 1889. The malady infests both younger and older plants. In the younger it causes a yellowish coloring and a general appearance of debility, with death of the leaves, commonly from the point backward. After midsummer, spots appear on the exterior of the sheaths which are more conspicuous on the inner side and at times more or less smeared with a gelatinous substance. No successful remedy has as yet been proposed.

Dry-Rot or Mold. The dry-rot or mold of corn (*Diplodia zeae* (Schw.) Lev.) was investigated by this Station in 1906, it being reported by a grower in Licking Co. He stated that he had been studying the development for two years; the first time noted, the mold area was small involving but part of one shock; the next year a larger area had been invaded and the year of 1906 he reported his losses were still greater. He reported that conditions clearly indicate the invasion of the soil by the parasite and possible infection through the growing plant. As in this case from Licking county and many others in which continuous corn growing is practiced on rather moist soil, there is great danger from accumulation or infection. The ears attacked were marked by adherence of the husk and the uniform moldy covering matted the kernels together upon the ear and destroyed the feeding value.

In the matter of prevention little can be done beyond avoiding continuous cropping of corn for invaded areas. For life history of the fungus see Circular 117, Illinois Experiment Station; 22nd Annual Report, Nebraska Experiment Station, 1908.

The Leaf Blight Fungus (*Helminthosporium graminum* Rab.) has been noted on corn and has recently been sent to this Station from Vinton county, in the latter case upon sweet corn. The fungus causes somewhat extended, or elliptical

brown (dead) areas in the leaf blades, readily identified by the microscope. All diseases of the young corn attract notice, but it is not certain that there is need to apply fungicides for this fungus, though such might prove successful.

Fig. 45. Stem of maize attacked by smut. The smut boils shown here later burst open and scatter masses of smut spores.

Corn Rust (*Puccinia Maydis* Berang.) is met with in greater or less abundance upon corn every season, the greater abundance usually being in rainy seasons. The rust causes small oblong or elliptical spots on the surfaces of leaf and sheath and in the spots are contained reddish-brown spores of the rust. The shade of the spores will vary with the time and development of the fungus. Here, as with wheat, the fungus passes through the uredo and teleuto stages.

Silage Mold. At times we have complaint of mold in silos where corn silage is stored. Doubtless there is some loss in nearly all cases from different molds or decays where the air circulates in contact with silage. We have investigated the mold fungus (*Penicillium* sp.). This is possibly the same blue mold which we have found to attack fruits in storage and transit. It is not an active organism and must be held in check by control of conditions in the silo.

Fig. 46. An ear of corn partly destroyed by smut. Other ears may be found showing different forms of attack.

Corn Smut is a well known disease, attacking leaves, shoots, ears, tassels and brace-roots of corn, converting the diseased parts into masses of dirty (smutty) spores of the fungus (*Ustilago Zeae* (Beckm.) Unger). A brief article upon corn smut will be found in Bulletin 78. (See also Bulletin 92 of the Kansas Experiment Station). The corn smut may be propagated by smutty seed, although much more likely to be carried by the transportation of the yeast spores of this smut fungus which may light upon any young growing part and produce smut infection. From this fact and from another—probably a greater

prevalence of the smut yeast spores in later summer—later growing parts, for example, tassels, brace-roots, ears and sucker shoots, are perhaps more often attacked by the smut. The smut spores may be scattered in manure if smutted fodder is used, and it seems well proved that manured land yields more smutted corn than unmanured. The same may be true of clover sod as compared with corn stubble. The reason would exist in the decayed vegetable matter, wherein the secondary yeast spores of the smut may grow and then may be carried to the corn which becomes thus affected. Treatment of seed corn does not apparently reduce the amount of smut. Cutting and burning the smut boils before they have burst open would be useful. It is worth while to fight smut by all available means.

COWPEA

Leaf-Spot. In southern Ohio where these are grown there is danger of the leaf-spot (*Cercospora*). This is not liable to be very serious.

Wilt. The wilt fungus (*Necosmospora vasinfecta tracheiphila* Erw. Sm.) is more serious, although at present largely confined to the southern districts. For Ohio conditions the practice of growing cowpeas is not of such extent as to threaten seriously with this disease.

CRABAPPLE

Scab. The same scab which attacts the common cultivated sorts also attacks the crabapple, including both fruit and foliage. The remedy is that given under apple.

Fig. 47. Cucumber leaf and stem attacked by Anthracnose. The dead areas in the cucumber leaf, caused by Anthracnose, are usually larger and more nearly circular in outline than with downy mildew.

Rust. The same rust fungus (*Gymnosporangium macropus* Lk.), in the cluster cup stage appears on the crabapple leaves and fruit as well as upon the leaves and fruit of apple, and leaves of crataegus. (See Apple).

CROCUS

Root-Rot. Little study has been made with us of the diseases of bulbous plants, yet we are liable to import those occurring in Europe. The common root infesting fungus, *Rhizoctonia*, is one of the determined troubles of crocus in France. Microscopic identification of the trouble should be easy owing to the characters of the fungus.

CUCUMBER

Anthracnose (*Colletotrichum Lagenarium* (Pass.) Hals.). This fungous disease attacks nearly or quite all curcurbits as well as the bean. Upon the cucumberin Ohio it is apparently more destructive during the earlier season. The fungus may be found in the greenhouses at all cultural periods, as well as in the field. It causes circular dead spots in the leaves, usually more than one-fourth inch in diameter, and likewise elongated brown areas on the stem. (See Bulletin 73, 89 and 105)

Unlike the downy mildew, anthracnose may be checked after it appears, though best prevented by earlier applications of the fungicide. In the field, Bordeaux mixture is to be preferred; in the greenhouse, copper sulfate solution, one pound to 50 gallons, has proved efficient and has checked the anthracnose after one-fourth of the plants had been destroyed by it.

Damping-off is a frequent trouble upon greenhouse cucumbers. It is serious often where plantings are made following lettuce attacked by rosette. The fungus in that case is the same as lettuce rosette (*Rhizoctonia*) or lettuce drop (*Botrytis*). There is a strictly damping-off fungus (*Pythium De Baryanum* Hesse) that is sometimes troublesome. The Botrytis named at times attacks pruned parts of cucumber plants, also extending its attacks to the blossom end of young fruits.

The results of Rhizoctonia on greenhouse cucumbers have been curious owing to attacks on the smaller root branches or rootlets. The growth of the vines is at times checked, accompanied by coloring of the leaves and reduced fruitfulness. Some growers have given the name "leaf-curl" to this phenomenon but it is strictly the effect of the fungus named. It has been found necessary in soil treatments where cucumbers follow affected lettuce to increase the strength of formalin drench to 4 or 5 pounds per 50 gallons of water. (See Soil Diseases).

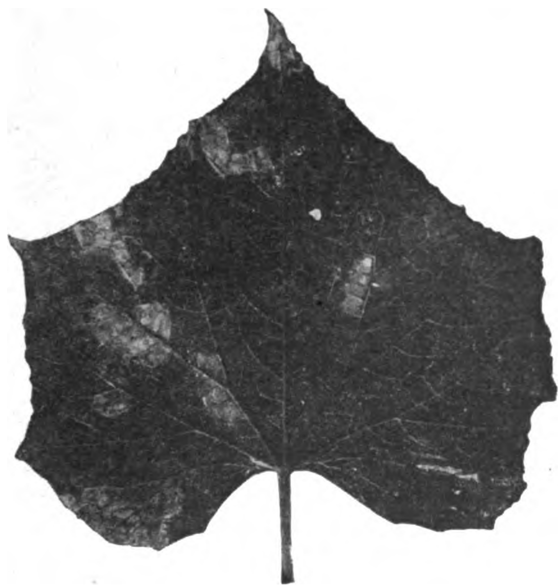

Fig. 48. Cucumber leaf from greenhouse, attacked by Downy Mildew. The spots in the leaves caused by the mildew are usually outlined by the veinlets of the leaf.—From a photograph by T. F. Manns.

Downy Mildew. Downy mildew fungus (*Plasmopara Cubensis* (B. & C.) Humph.) is late in its attacks, not having been found in Ohio fields earlier than August 3rd. It causes angular, yellowish spots on the leaves, followed by yellowing of the whole leaf and death, as by frost. It spreads with extraordinary rapidity, requiring only three or four days to become disseminated throughout a large field. Unlike anthracnose, it may not be successfully checked after its appearance, and it is not safe to leave untreated plots in fields to be sprayed. July 25th to August 1st is sufficiently early to begin spraying for mildew, but applications should be repeated at intervals of 7 or 9 days. In 1898 an increase of 75 bushels per acre, of sprayed over unsprayed cucumbers, was obtained at Creston. (Bulletin 105). Cucumber pickle growing finds in this mildew its most serious enemy. If any of the crop is to be harvested after August 20-25 spraying with fungicides appears necessary. Early planting may permit gathering the crop before this date. The downy mildew is also very destructive in the forcinghouse, and is to be treated with the same fungicides recommended for anthracnose. (Bulletins 73, 89 and 105).

Leaf-spot of cucumber is also due to fungi. (*Phyllosticta Cucurbitacearum* Sacc. and *Cercospora Cucurbitae* E.&E.) Of the two species named, the Phyllosticta was the commoner in thrifty pickle fields in 1898; the Cercospora being apparently confined to wet fields, though this cannot be expected to hold true under all circumstances. The Phyllosticta was found almost exclusively upon the unsprayed pickle plants and seems, therefore, amenable to the same treatment as applied for downy mildew. (Bulletin 105).

Mosaic Disease of greenhouse cucumbers has been recently studied in Ohio. This disease is analagous in character to the mosaic disease of tobacco and tomatoes and to the yellows of the peach. It is due to an oxidizing ferment in the leaves and is transmitted like the tobacco mosaic disease, by touching first diseased and then healthy plants. The fruitfulness of these variegated yellow plants is very low and it is best at all times upon the appearance of the disease to remove the diseased plants and destroy them.

Nematodes or Eelworms (*Heterodera radicicola* (Greef.) Mull.). These minute parasitic worms are often very destructive upon cucumbers under glass. They are especially so in some cases recorded in Bulletin 73. The greatest injury may occur on the seedling plants, but plants of all ages are destroyed by the parasitic worms. Their presence may be known by the small, bead-like enlargements produced upon the roots or rootlets. This matter is treated at some length in that Bulletin. No remedy has been discovered that is effective with plants once attacked by eelworms. The time to prevent this trouble is in the selection or preparation or treatment of the the soil for greenhouse benches. Indeed the nematodes seem to be present in old sod, and to some extent in decaying vegetable matter generally. An effective remedy against eelworms consists in steaming and so treating the soil that the parasites will be destroyed. For this procedure see calendar and Bulletin 73. Also Massachsetts Exp. Sta. Bul. 55, In thus handling the soil due time must be given for draining and drying.

Fig. 49. Roots of seedling cucumber with Nematode galls upon them. These cause collapse of the plants.

Powdery Mildew (*Erysiphe Cichoracearum* DC.) of cucumbers is also frequent in the forcing house, but rarely destructive elsewhere. For this fungus a dilute copper sulfate solution is effective. See Bulletin 73.

Root-Rot. The root-rot or so-called "leaf-curl" development on matured cucumber plants referred to *Rhizoctonia*, is often serious. It is more fully discussed under damping-off above.

Spot of Cucumber Fruit or Cucumber Scab (*Cladosporium cucumerium* Ell. & Arth.), has been reported upon cucumbers by Dr. Arthur (Ind. Exp. Sta. Bul. 19), and may prove injurious if prevalent. It should be found amenable to the same treatment recommended for anthracnose and downy mildew.

Cucumber Wilts. The wilt diseases of cucumbers, likewise of other cucurbits, are a source of usual complaint in the earlier season, as the plants are beginning to form vines. In 1899 these complaints continued much later. The plants suddenly wilt down as from lack of water, then soon die. What has been referred to the same general cause was also observed in the cucumber forcing-house, apparently starting in the leaves. Smith (Proc. Am. Ass. Adv. Sci. 1893) refers this disease to a bacterium (*Bacillus tracheiphilus* Smith) which is transferred from diseased to healthy plants by the cucumber beetle and the squash bug. This form of wilt has been found on cucumbers, muskmelons and squashes

in Ohio. In addition we have found to a limited extent, another wilt disease of the cucumber which appears to be similar to that described by Dr. Smith. (Proc. Am. Ass. Adv. Sci. 1895, p. 190). On watermelons in the South he finds a trouble with which ours may be identical. (Bul. 105, p. 222). This latter is referable to a species of fungus, a fusarium (*Fusarium niveum* Smith), which grows internally in the stem and finally plugs up the water vessels in a manner similar to the work of the bacterial wilt. Spraying is unlikely to be beneficial for this wilt or for the bacterial one. Preventive measures suggest gathering and burning infected vines, and especially waging a successful war against the insects; these should prove more or less successful according to thoroughness of work. The fusarium wilt calls for rotation of crops. Much may be finally done by breeding varieties resistant to wilt.

CURRANT

Anthracnose. The anthracnose (*Gloeosporium ribis* (Lib.) Mont.) of the currant has occurred occasionally and will apparently be checked by the same treatment as given for raspberry anthracnose.

Cane Blight is a very serious disease whenever stools are attacked by it. The fungus (*Nectria cinnabarina* (Tode) Fr.) survives by its threads in the tissues of the stool and upon the death of the canes develops as a bright pink mass of the fungus upon dead parts. While spraying may, and surely must, keep down the risk of infection, whenever stools show attacks by dying of a part of the canes and the development of this fungus these infected stools are doomed and should be removed and burned.

Black-Knot. A black knot fungus (*Plowrightia ribesia* Pers.) has been described upon currant, and is always a possibility with us. It attacks the branches or stems.

Dropsy. This disease has been met with. It causes very considerable enlargement upon the young stems of the currants, not unlike in appearance the enlargements due to crown gall in the peach, except that usually more of the stem is involved than in the other case. The trouble appears to be due to physiological causes and the pruning knife may aid cultural efforts.

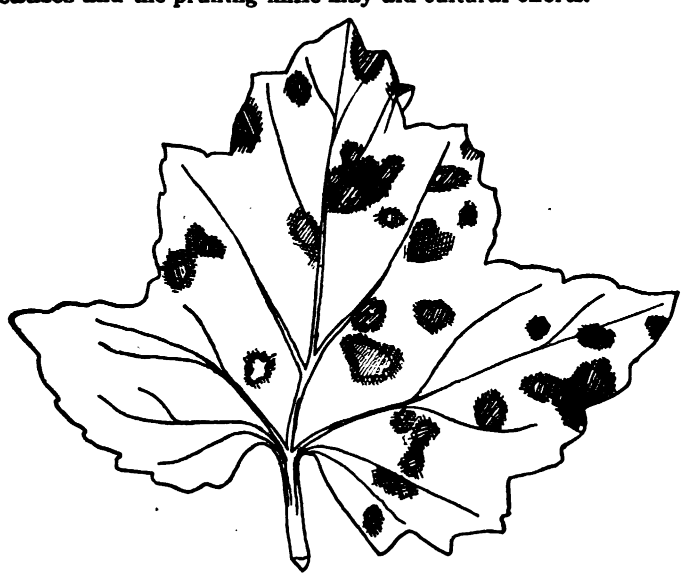

Fig. 50. Leaf of currant attacked by leaf-spot. The dead areas are easily seen in the currant leaf but the fungus is difficult to discover

Knot. This fungus (*Pleonectria berolinensis*, Sacc.) is a stem trouble of currants and calls for investigation. It has been collected in this state.

Leaf-Spot of currants is referable to two species of fungi (*Septoria ribis* Desm.; *Cercospora angulata* Wint.) of which only the Septoria has been discovered in Ohio. (See Bulletin 79). These fungi produce early spotting and premature dropping of the currant foliage; in some instances the leaves drop even before the fruit has ripened. Bordeaux mixture applied as per calendar is effective against this disease, though late applications may render it necessary to wash the fruit. For this reason, if for no other, the first application should be made very early and followed by about two more at fortnightly intervals.

Rust. A rather common rust fungus (*Puccinia ribis* DC) has been discovered upon currant. Warning has been recently sent out against a second fungus (*Cronartium ribicolum* Dietr. *Peridermium strobi* Kleb.) which attacks the seedlings of white pine in the aecidial stage, and passes its uredo and teleuto stages *upon leaves of currants and gooseberries.* This fungus is to be sought for with care since its occurrence in the United States may have much to do with the success of forest plantings of white pine.

Powdery Mildew of gooseberries (*Sphaerotheca mors-uvae* (Schw.) B.&C.) sometimes attacks currants where it is apparently less destructive than on gooseberry. Reasonable spray treatments should control it.

DEWBERRY

Leaf-Spot. (*Septoria rubi* West.) Cultivated dewberries as well as the wild sorts, are peculiarly susceptible to the attacks of the leaf-spot fungus. It causes very small grayish spots in the leaves. The same fungus attacks blackberries and raspberries, as previously stated. It may be prevented by a careful application of Bordeaux mixture.

Rust. The bramble rust also attacks the dewberry as in the case of blackberry. For treatment see blackberry.

EGG-PLANT

Anthracnose. The anthracnose fungus of egg-plant (*Gloeosporium melongenae* Ell. & Hals.) attacks the fruits of egg-plant and causes spots in them. This occurs frequently in Ohio. These show early as pits in the surfaces of the fruit which show the usual border.

Bacterial Blight. The common solanaceous blight organism (*Bacterium solanacearum* Erw. Sm.) attacks the egg-plant as well as the potato and tomato. Where attacks occur destruction of the affected plants is all that can be done.

Fruit-Rot. A fruit-rot of egg-plant likewise occurs and may at times appear as a leaf-spot fungus. This, like the anthracnose and leaf-spot, should yield to treatment by sprays. Ammoniacal copper carbonate may be used toward the ripening period.

Leaf-Spots. Two or more leaf-spot fungi have been recorded on egg-plant and will doubtless be found when sought.

Stem-Rot. The stem-rot fungus of sweet potato (*Nectria ipomoeae* Hals.) has been described upon egg-plant by Dr. Halsted. The conidial stage is evidently a species of fusarium and it may or may not be a different one from that with which we have to contend upon the potato; it is recorded by Dr. Halsted as the same that occurs on sweet potato.

ELM

Bleeding. Bleeding of pruned elm trees is often annoying as well as dangerous. Mr. Boddy, City Forester of Cleveland, thinks asphaltum covering over cut surface reduces or cures the bleeding. This is successful when searing by torch precedes application of dressing.

Black-Spot. The leaves of ornamental elms are attacked by black spots (*Dothidella ulmi* (Duv.) Wint.) (*Gnomonia Ulmea* (Sacc.) Thuem.) which sometimes injure the leaves, and by this means checks the tree.

Other **Leaf Diseases** also occur upon the elm. One of these is a leaf-spot (*Phyllosticta ulmicola* Sacc.) which matures its spores in the fallen leaves. Gathering and burning these infested leaves will prove a check on this fungus.

The **Powdery Mildews** (*Microsphaera Alni* D.C. and *Uncinula macrospora* Pk., more often the latter) likewise attack elm leaves. If troublesome these should be reached by applications of Bordeaux mixture, making the first application when the leaves are half grown.

Timber-rots are also known on the elm; to be guarded against in wound infection of shade trees.

Twig Disease. In portions of Ohio and in Kentucky a dying of elms which are prized as shade trees has been reported. This disease shows first as a loss of leaves at the ends of twigs, often at the tops of trees. (See Kentucky Exp. Sta. Bul. 84). It is believed by Prof. Garman that changing soil conditions have much to do with this disease. To the writer it would seem that the water factor with this, as with many other shade trees, may prove a determining cause. At any rate, the time has come for a study of these water problems in shade trees.

EMMER

Anthracnose, Scab, etc. Emmer and its near relative, spelt are attacked in Ohio by the Anthracnose (*Colletotrichum cereale* Manns) and by the scab (*Fusarium roseum* Lk.) These diseases are the same as those occurring upon rye, wheat and other cereals under which heads fuller notes will be given. (Also see bulletin 203).

FIG

Leaf Diseases. The fig is frequently grown in conservatories and is often attacked by leaf diseases. The commonest leaf fungus (*Cercospora Bolleana* (Thuem.) Speg.) of the Mediterranean region is a serious leaf disease. The attacked spots assume a brown color, the leaves eventually yellowing and dropping off. Where leaves of fig begin to drop from such causes, a spraying with Bordeaux mixture should be applied upon the younger leaves.

FILBERT

Black-Knot (*Cryptosporella anomala* (Pk.) Sacc.) has been found upon cultivated filbert or hazel-nut in New Jersey and Massachusetts (N. J. Exp. Sta. Rept. 1892 and Mass. Exp. Sta. Rept. 1892). This is a serious stem disease which may check successful culture when it occurs.

FLAX

Dodder. Flax is attacked at times by a seedling parasite, flax-dodder (*Cuscuta Epilinum* Weihe) whose tiny, leafless stems wind about the flax plant and by haustoria, or sucking organs penetrating the epidermis, draw from it substances essential to healthy growth. The dodder seeds are carried in the flax seed and prevention must seek to avoid the seeds.

Other Diseases of flax are noted to occur in the Northwest among which are a Fusarium wilt and a Colletotrichum blight. (See bulletins 50, 55 and 71, North Dakota Exp. Sta.).

FOREST SEEDLINGS

Forest seedlings as will be noted under Catalpa, Pine and Spruce are especially liable to certain disease attacks upon the young plants. The number and variety of these diseases is scarcely realized until one begins to care for their survival as in forest culture. It will usually be found in newly cleared areas used for this purpose that the leaf mold is badly infected with seedling parasites. Some treatment of this soil before using as seed beds is desirable. For some of the commoner damping-off fungi the formalin drench may succeed. For coniferous seedlings, other treatments may be required. Recently the United States Department of Agriculture has reported upon two methods of treatment which consist of the use of dilute sulphuric acid, or mixtures of lime with powdered copper sulfate. (See circular No. 4, Bureau of Plant Industry, United States Department of Agriculture).

GINSENG

Leaf Blight or Leaf-Spot, (*Alternaria* sp.) occurs upon ginseng plantations. These have been checked at times by spraying with Bordeaux mixture, while at other times the sprays being made immediately before cold weather caused serious losses.

Root-Rot. The root-rot fungus (*Thielavia basicola* Zopf.) has been found in New York by Van Hook to attack the roots of ginseng and cause destructive rotting. This may prove a serious drawback to ginseng growing, and methods of prevention are difficult to propose. (See Cornell Exp. Sta. Bul. 219).

GOLDEN SEAL

Leaf-Blight of golden seal occurs in many plantings. It is due to a fungus of the same genus (*Alternaria*) that proves troublesome on leaves of ginseng. Spray applications need to be worked out for it.

GOOSEBERRY

Leaf-Spot. The gooseberry leaves are attacked by the same leaf-spot fungus recorded upon the currant (*Septoria ribis* Desm.), although the defoliation may be even more severe than on the currant. In spraying experiments at this Station, conducted by the Horticulturist, it has been found that the gooseberry leaf-spot is more easily prevented than the currant leaf-spot. Indeed no fungus disease upon which we have experimented is more easily prevented when the fungicide is applied at the proper time. (See Spray Calendar). Often the leaves from gooseberry plants have all dropped before maturity of fruit, and in hot weather all the fruit has been lost on the unsprayed, check plants, while the sprayed plants gave a fine yield of satisfactory fruit.

Powdery Mildew (*Sphaerotheca mors-uvae* (Schw.) B. & C.) is a destructive fungus disease especially common upon English varieties, such as Industry, Crown Bob, &c. It has been destructive also upon the Houghton. As already stated this mildew attacks currants. From the nature of this fungus the first spraying with Bordeaux mixture should be made early in the season. (See Bulletin 79). Subsequent applications may be either of Bordeaux mixture or potassium sulfid. (See Calendar). After fruit is half grown the latter fungicide is to be preferred since it is more easily removed from the fruit.

Rust. See currant rust.

GOURD

Anthracnose, Downy Mildew, &c. Gourds are susceptible to the same fungus diseases as the cucumber. The two most conspicuous are anthracnose and downy mildew. The anthracnose, especially, causes spotting and discoloration on the gourds. This may be arrested if, when the gourds are gathered, they are subjected to treatment with scalding water; otherwise the development of the fungus continues while the disfiguring increases. Field treatment in this case is the same as recommended for like diseases of the cucumber.

GRAPE

Fig. 51. Grapes attacked by anthracnose, also called Bird's-Eye Rot.

Anthracnose. As is well known we have a long list of fungi attacking the grape, among them the anthracnose fungus (*Sphaceloma ampelinum*) which is found upon leaves and stems as well as the fruit, causing definite sunken spots, usually with a central area of lighter color. Upon the fruit the appearance has suggested the name "bird's-eye-rot" and the last the name bitter-rot. Where prevalent the anthracnose may be entirely prevented by following the directions in the use of Bordeaux mixture as given in the calendar.

Bitter-Rot (*Melanconium fuligineum* (Scrib & Viala) Cav.) of the grape is sometimes prevalent but perhaps less frequent in Ohio than the black-rot.

Black-Rot (*Guignardia Bidwellii* Ell.) is one of the most troublesome and destructive of grape diseases. It chiefly attacks the fruit and causes dark spotting and rotting of the green berries, but it may also attack the leaves, petioles and cluster branches, producing circular or elongated dead spots in them. The rotted fruits persist upon the branches and may hang on over winter, thus carrying the fungus from year to year. This disease, if neglected, is very destructive and the longer the neglect the greater is the difficulty in prevention. Because of the circumstances stated, delay in beginning the treatment increases the difficulty. It is apparently essential that first applications of fungicide for the black rot be made while the vines are dormant and that these be very thorough, followed by the later applications as per calendar. Omission of the spraying just before the blossoms open may lead to ragged clusters, from dropping of the small grapes. (See report of the U. S. Dept. of Agr. 1896). (Ohio Exp. Sta. Bul. 130).

Fig. 52. A cluster of grapes attacked by Black-rot. The rotting grapes are light brown in color immediately following decay.

Crown-Gall. Crown gall of the grape is known to give trouble in Ohio. This comes as enlargements near the crown and on the roots. The latter occurring upon raspberry, peach, etc. It is believed to be due to the same cause as the other crown galls and to be handled only through removal

Downy Mildew (*Plasmopara viticola* (B. & C.) Ber. & D'Ton) of the grape is a prevalent fungus disease which has long been known and repeatedly studied. By it the leaves are attacked and the fungus forms in them öospores by which the winter is passed. The fungus also attacks the berries, causing brown-rot. Gathering and burning the fallen leaves may therefore be useful. No particular difficulty attends the prevention of downy mildew if spraying is thoroughly done.

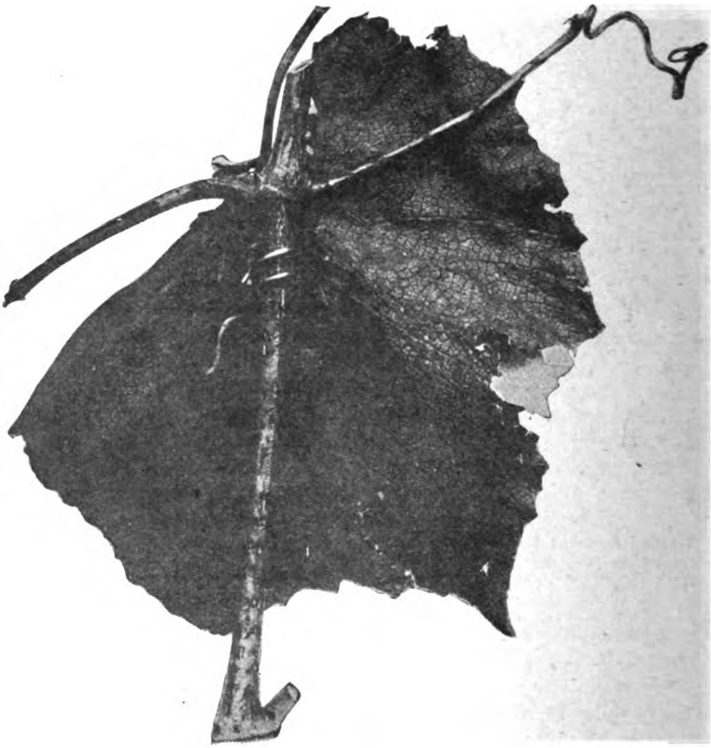

Fig. 53. Leaf and stem of grape attacked by Black-rot. The lesions in the stem are dark colored. Those in the leaf show as dying areas.

Powdery Mildew (*Uncinula necator* Schw.) is likewise prevalent upon both leaves and fruit. Like all powdery mildews the parts attacked are covered over by the web-like threads of the mildew fungus. This is successfully prevented by the use of Bordeaux mixture as elsewhere directed. (For illustrations of grape diseases see Report U. S. Dept. of Agriculture 1886 and 1887; also Scribner, "Fungus Diseases of the Grape, etc.").

Stem Cankers. Stem cankers of the grape are rather frequent. Many of these are due to injury caused by freezing by which dead spots are produced and in the process of healing these injuries become surrounded by excessive growth and enlargements. In some instances the enlargements obtained a diameter of two or three times the size of the stem. The preventive measures are the same as for any freezing injury, viz., drainage and prevention of excessive late growth.

Dying of grape canes has been studied in one vineyard where it appears also to be associated with crown gall and to result from other diseased conditions. (See circular 64). In this case a portion of the vineyard died out almost completely; followed by sprouting of a portion of the roots. In August there was wilting and drying up associated with diseased stem conditions.

Fig. 54. Illustration showing stroma of a fungus believed to take part in death of grape stalks. The separate dot-growths are at times united into elongated ridges. From Circular No. 64.

The history of this case indicates that the removal and replanting of vines will be more successful than to endeavor to start vines again by sprouts from bases of injured vines.

White-Rot. Diseased conditions of the earlier stages of black-rot showing light color of the berries leads to the use of the term white-rot. As yet, however, the writer has never conclusively proved that we have a white-rot development different from this stage of the black-rot of the grape in Ohio. Where growers suspect this form of rot the method of treatment is the same as for black-rot.

GRASSES

Anthracnoses, Smuts and Rusts are found upon the grasses. These are in part described under blue-grass, orchard-grass, red-top, timothy, and chess.

HAZELNUT

See Filbert.

HEMLOCK

Hemlock grows freely with us and is apparently quite free from foliage troubles.

Heart-Rot (*Trametes pini* (Brot.) Fr.) and Sap Rot (*Fomes pinicola* (Sw.) Gill) are reported from districts where special attention is given to the conditions.

HICKORY

Leaf-Spot. A hickory leaf-spot (*Marsonia juglandis* (Lib.) Sacc.) is quite general and leads to dying of the leaves prematurely. This really merits much closer study than has yet been given it in our state.

HOLLYHOCK

Anthracnose (*Colletotrichum malvarum* (Braun & Casp.) Southw.) An illustration has been published in the Journal Mycology (Vol. 6:46-48). It may attack any part of the plant, and is a serious trouble where it occurs.

Leaf Blight (*Cercospora Althaeina* Sacc.) is another fungus disease of the hollyhock. These two diseases of the hollyhock should be amenable to spraying with standard fungicides.

Rust (*Puccinia malvacearum* Mont.) On the other hand this recently introduced disease of the hollyhock is much less likely to be prevented by spraying. The rust fungus forms dense patches, spots or sori, on the under side of the leaves. These are commonly about one-sixteenth inch or more in diameter, of grayish-brown color and projecting below the leaf surface, while a minute yellow spot early appears on the upper surface of the leaf. Subsequently the diseased leaves drop and by the time the plants are blooming the the stem below is bare or disfigured by the remains of the diseased leaves. At the Station this rust has been prevalent and the complaint is general respecting the same trouble. It would seem wise to gather and burn all the affected leaves and likewise the old stems as early as possible. Between anthracnose and rust these popular old flowers are having, at present, a difficult time of it.

HORSE-CHESTNUT

Leaf-Spot of the horse-chestnut (*Phyllosticta paviae* Desm.) is quite frequent. During 1908 and 1909, tip-burn was associated with leaf-spot; as near as could be determined, the tip-burn followed punctures of leaf hoppers or other insects and the plants made very restricted growth during the season. It may be necessary to take combined spraying applications for leaf-spot and the insect troubles. Bordeaux mixture is recommended for this purpose and has in the past given very satisfactory results for leaf-spot. The first application should be made when the leaves are about half grown, to be followed by others at intervals of three weeks.

HORSERADISH

Leaf Blight (*Ramularia armoraceae* Fckl.) is frequent upon horseradish and is also found upon other mustard plants. Ordinarily the severity of attack does not call for spray treatment.

Leaf-Spot (*Cercospora armoraceae* Sacc.) is less frequent and not serious in its effects.

White Mold (*Cystopus candidus* Pers) which is so common upon shepherd's purse and other low plants of the mustard family, likewise attacks horseradish. Owing to the heavy root development of horseradish the temporary parasitic attack does not give noticeable injury.

HYDRANGEA

Leaf Blight. A leaf blight fungus (*Phyllosticta Hydrangeae* E. & E.) has been observed on Hydrangea by Dr. Halsted in New Jersey. This may be serious at times upon this ornamental plant.

Rust. Hydrangea is likewise attacked by the rust fungus. (*Melampsora Hydrangeae* DC.) This may also be at times, quite serious. Remedies for neither of these troubles have as yet been worked out.

IRIS

Bulb-Spot. Massey has reported a fungus causing black patches on the surfaces of iris bulbs. This fungus (*Mystrosporum aductum* Mass.) from a description given, resembles onion smudge in its appearance and effects. Loss is prevented by soaking the bulbs for an hour in Formalin solution.

Leaf-Blight. The leaves and roots of iris have been reported in England to be attacked by a fungus. (*Botrytis galanthina* Mass.) This disease is likely to be present in shipments of iris about the world. It is described as first attacking the leaves and later destroying the root, thus causing the death of the plant.

IVY

Leaf-Spot and Leaf-Blight. Leaf diseases of English ivy are occasionally reported but have not been studied for our district. Dr. Halsted has described a blight upon variegated forms of English ivy (*Vermicularia trichella* Hals.). In this connection we need to bear in mind that variegated plants are especially susceptible to disease and are therefore liable to suffer.

JAPAN CREEPER

See Virginia Creeper.

LARCH

Canker and Rots. Larches are but little grown in our territory. In Canada there has been described a larch canker (*Peziza willkomii* Hartig.) This attacks the trunk and branches. In common with other conifers the larch suffers from tree infecting rot fungi. The lack of American data upon these diseases emphasizes our need for such studies.

LEMON

Greenhouse specimens of lemon trees are a source of a good many inquiries. These are chiefly leaf diseases which arise from the brown molds and other fungi infesting these plants. As a rule they are amenable to spray treatments with standard fungicides.

Rots. Allusion has been made to storage and transit rots of citrus fruits. The lemon is no exception to the attacks of these rots. The blue mold (*Penicillium*) is a very common form, and may be met with in almost any of the ordinary shipments of lemons. Brown-rot (*Pythiacystis citrophthora* R. E. Sm.) is a serious trouble in California lemons especially. It appears as a white mold on the surface of affected fruit.

LETTUCE

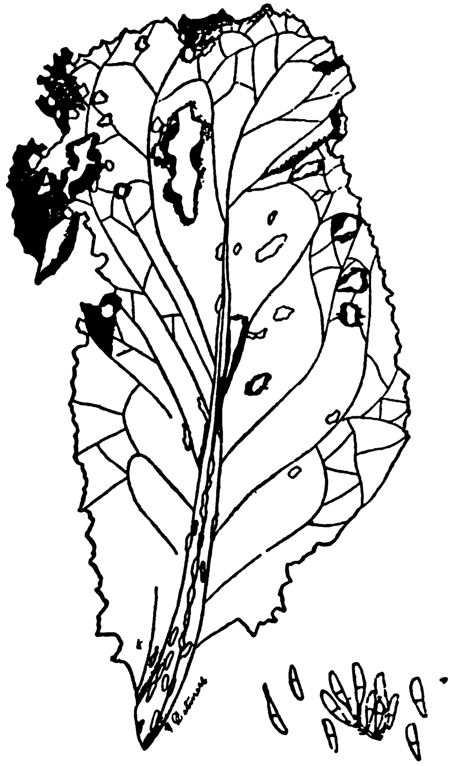

Fig. 55. Lettuce leaf attacked by Anthracnose. The dead spots caused by this fungus frequently break loose and drop out, causing perforation of the leaves. On the midrib the lesions are deep-seated. The two celled spores are shown highly magnified. From Bulletin 73.

Anthracnose or Leaf Perforation. This disease of lettuce was discovered by the writer in 1896 and sent to Dr. J. B. Ellis for description of the fungus (*Marsonia perforans* E. & E.) It shows upon the lettuce plants as dying of spots in the leaves which break free and drop out. The fungus also produces lesions in the midrib of the leaf. In cases of young leaves the attacks of the fungus causes distortion of the leaf, especially toward the top. Apparently very few plants recover after being once attacked, although one may reasonably keep down this disease in the seed beds and young plants by the use of Bordeaux mixture. For houses once seriously infested, thorough fumigation and soil treatment would probably be profitable. It is not generally distributed.

Downy Mildew (*Bremia Lactucae* Regel) is the work of another fungus which belongs to the same class as the downy mildew of the cucumber. It forms yellow spots in the upper leaf surface which appear below as whitened, downy covered areas. Like the downy mildew of cucumbers this one may spread very rapidly under favorable conditions, such as warmth and surface watering in the greenhouse. Keeping water from the foliage by subirrigation of the beds has been found very beneficial (Bulletin 73). Gathering and burning the diseased leaves or plants will usually repay the labor. Particular attention to heat and moisture will usually render spraying unnecessary and it is certainly inadvisable except to eliminate the fungus from the house. Avoid too high temperature or too much moisture on plants.

Rosette or Rhizoctonia. This is a very troublesome disease of greenhouse lettuce which arises from the accumulation of the sterile fungus (*Rhizoctonia* sp.) in heavily manured soils used for continuous greenhouse culture. Upon the young seedlings the Rosette fungus produces stem lesions and rotting off or damping off of the plants (Fig. 57) or with larger plants which are later attacked upon the branch roots or rootlets, the restricted root development prevents growth of the plant axis and gives a basal development of normal leaves with a rosette-shortened center of leaves. Where serious, the crop is shortened very much and

the loss of stand on smaller plants is frequently very heavy. Good results in prevention have been obtained, both from steaming and from formalin drench as per directions in seed and soil treatments. The fungus also attacks the succeeding crops of tomatoes, cucumbers, etc. Attention must in all cases first (be given to growing healthy seedling plants, to be followed by soil disinfection. See Circular No. 57).

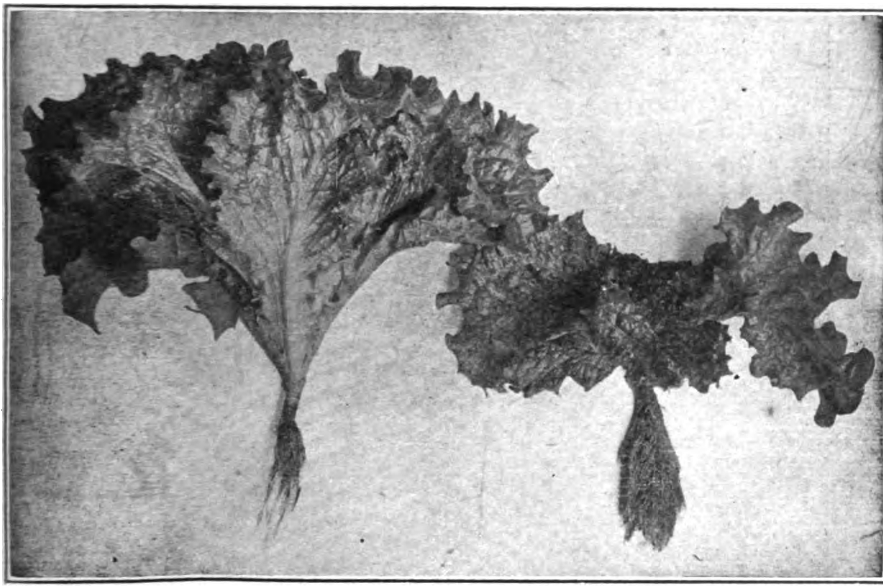

Fig. 56. On the left is shown a healthy lettuce plant, on the right diseased lettuce plant with Rosette effects produced by inoculation of pure culture of Rhizoctonia. The effect of the Rosette Fungus is shown in destroying absorbent rootlets and in the growth of additional new roots; it also prevents the proper development and elongation of the axis or stem of the plant. From Circular No. 57. (See also Fig. 57).

Lettuce Rot or Lettuce Drop. This is by all odds the most troublesome disease to the lettuce grower. The plants may rot off at the surface of the earth and the central parts, especially of head lettuce, may become attacked by the rot fungus (*Sclerotinia Libertiana* Fckl.) (*Botrytis vulgaris* Fr.). The fungus appears as a whitened covering with a liberal production of spores in clusters. At this Station it has not been possible to succeed with the head lettuce because of the rot. Fumigation of house, the use of fresh or steamed earth each year and the careful regulation of temperature and water supply, seem to be the measures most favorable to prevention. A low night temperature, less than 50 degrees F. is very desirable, while too high a temperature will usually result in disease. Ventilation is all essential during the day. It is desirable also to gather and burn rotted leaves and plants.

Leaf-Spot. The leaf-spot fungus (*Septoria consimilis* E. & M.) is frequent upon wild lettuce plants and occassionally upon outdoor lettuce, especially in late seasons. The small characteristic leaf-spots are not difficult to distinguish from anthracnose. The remedies are confined to avoidance.

Root-Rot and Stem-Rot. A bacterial stem-blight has been described from Vermont, but has not been found with us. A recent stem-rot infection closely resembles rosette in the behavior and form of affected plants. Microscopic

examination shows that the stem tissues are somewhat brown and that the brown and dead rootlets are occupied by the fungus which is referred to a species of Fusarium. This disease is at present under investigation and should be controlled, if at all, by the thorough soil treatments recommended under lettuce rosette. It will be no use to disinfect the houses and then grow plants in diseased soil.

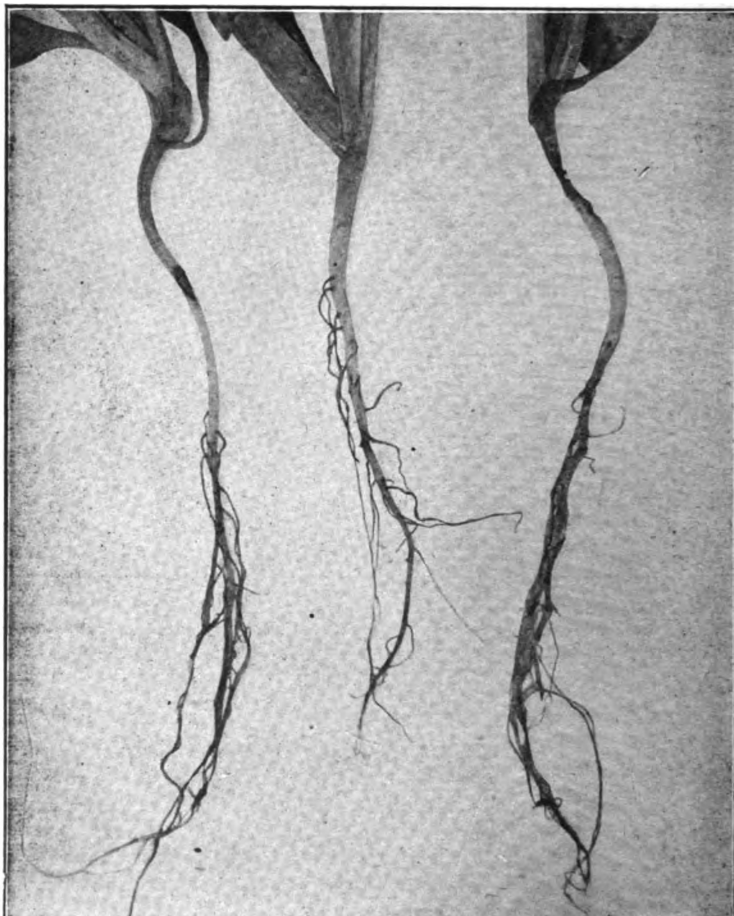

Fig. 57. This shows root portions of seedling lettuce plants with dark spots, lesions caused by attacks of the rosette fungus, *Rhizoctonia*. With the younger plants these attacks cause large mortality and in very small seedlings the stem of plantlet may early collapse after the manner shown in rotting specimens. (From Circular No. 57).

Tip-burn. Tip-burn of lettuce leaves is often brought to notice. Usually it is associated with unsatisfactory watering in the greenhouse, or with extreme changes to summer weather. The remedy consists in the methods of watering employed.

LILY

Lily diseases are frequent in all lily growing districts. With us no study has been made, as little complaint is made to us. Doubtless the chief factor is to secure healthy bulbs.

LOCUST

Heart-Rot (*Trametes robiniophila* Murr. and *Fomes rimosus* Berk.). In southern Ohio the locust is reported as suffering from a heart rot trouble, but to which of the several species occurring in different parts of the United States, we must ascribe most injury we are not yet able to decide. Both species occur in Ohio. The rot is described as infecting the heart of much of the trunk, so that trunks may be of no value above the first post length or less from base. The heart wood is converted into punk and the fungus fruits externally, as is commonly the case.

LUPINUS

Several species of lupinus are used for ornamental or other plantings and are liable to the same group of diseases as are found upon alfalfa, clovers and pea.

MANGEL-WURZEL

Mangel-wurzel being a near relative of the beet is liable to be attacked by essentially the same diseases as the garden beet. These are usually leaf-spot, rust, dry-rot, etc.

MAPLE

Anthracnose. (*Gloeosporium apocryptum* E. & E.) This disease attacks young Norway maples (See N. Y. Sta. Report '95) and has been also identified on the young shoots of sugar maples in Ohio. The new leaves were reported destroyed by the fungus which is much more common in Ohio on sycamore trees. Applications of Bordeaux mixture should check this disease.

Rhytisma and Leaf-spot. The leaves of cultivated maples are often disfigured by dark colored incrustations following the line of the veins. These incrustations are almost black and are caused by a fungus, (*Rhytisma acerinum* (Pers.) Fr.) The trouble is usually not serious, but if prevalent it would seem advisable to gather and burn all leaves attacked by it. The leaf-spot fungus (*Phyllosticta acericola* (Cke. & Ell.) often causes small spots, or dead areas, in the leaves. This may sometimes prove so serious as to call for applications of fungicides.

Mildew. Maple leaves are overrun by the powdery mildew fungus (*Uncinula*) at times, but this is not difficult to check even if spraying becomes necessary.

Tip-Burn—Sun-Scald. Tip-burn conditions upon the maple in 1908 and 1909 were similar to those described for horse chestnut and evidently due to secondary consequences of insect punctures.

Sun-Scald or winter injury effects are frequent upon maples after the manner of those described for apples. They are due to a killing of unripened tissues by premature freezing and are only preventable by avoidance.

MILLET

Leaf-Spot. Leaves of millet, dying from small, light-colored spots, were recently examined. These spots are due to a fungus (*Piricularia grisea* (Cke.) Sacc.) and the dying may at times be enough to shorten the yield of forage.

Smut. The seeds of millet are often attacked by the millet smut fungus (*Ustilago Crameri* Kornicke) which transforms them into black masses of smut spores, much after the manner of stinking smut in wheat. This is liable to injure the feeding value of the millet, although it is not likely that the smut will injure stock when millet is fed in the usual quantities. All smutted grain, of course, is ineffective and useless, and the smutted seed when again sown will produce a smutted crop. The smut is prevented by the same hot water seed treatment as that applied to prevent oat smut. In experiments conducted by the Botanist of this Station this treatment was successful.

MULBERRY

Bacterial Diseases. Russian varieties of mulberries have new growths, especially new sprouts attacked by a bacterium. These deep dark lesions result in cankers and all the various phenomena of the plant's effort to heal a wound in the wood. The trouble is so difficult to handle that where Russian mulberries are badly attacked, rejections may be necessary.

Leaf-Spot. Mulberries are at times attacked by a leaf-spot (*Cercospora moricola* Cke.) but this is rarely serious in our district.

MUSKMELON

Anthracnose. The common anthracnose fungus of the muskmelon (*Colletotrichum Lagenarium* Pass.) is the same as that of the cucumber. It attacks the stems of plants of all sizes as well as the leaves, resulting in the lesions of the stem and dead spots in the leaves. In these the fungus produces the fruiting bodies. After the seedling stage is passed it is usually possible to keep the anthracnose in check by the spraying as recommended for cucumbers.

The fruit anthracnose of the muskmelon (*Colletotrichum oligochaetum* Cav.) is widely distributed and has occured with us. It forms yellowish, diseased spots on the fruits and may disfigure them considerable. It is too soon with us to estimate possible losses from it. Thorough spraying with Bordeaux mixture should hold it in check if begun on the young fruits and repeated once or twice at intervals.

Black-Spot. In 1908 a case of black-rot or spot-rot of muskmelon fruits was reported with specimens. The spots were depressed and accompanied by decay. No definite causal organism was determined, although one or more were present in the spots. It is believed that spraying will hold it in check but the case was referred to us to late to test this.

Downy Mildew of muskmelon is caused by the same Plasmopara fungus as the downy mildew of cucumbers. As we have the fungus in Ohio it does not appear until towards the middle of August, but is then very destructive, sweeping rapidly over the melon fields and leaving only devastation behind. In its attacks the spots of the muskmelon leaves are somewhat different in shape and usually of a darker color than in the case of the cucumber. One with experience can readily distinguish by the use of an ordinary hand-glass. He will then see on the under side of the leaf the violet spores and spore-bearing

threads of the mildew fungus. The melons which are unripened upon the vines when attacked by mildew are practically worthless and for this reason large losses are usually incurred. The treatment is by Bordeaux mixture, as for cucumbers.

Muskmelon Leaf Blight is a disease more or less peculiar to the muskmelon, although the fungus (*Alternaria sp.*) which causes it has also been found upon cucumber leaves. The leaf blight causes rather large dead areas in the leaves which are usually distinguished from those of downy mildew by their larger size and the tendency of the central portion to break out. The prevention of muskmelon leaf blight is by no means an easy matter, requiring of itself great thoroughness and carefulness in the application of the Bordeaux mixture and also requiring that the downy mildew shall be watched during the same period. For this reason earlier sprayings, if made before August 1st, should be repeated at fortnightly intervals, while those after August 1st should be at weekly or ten-day intervals. Melon growers have succeeded by following these lines, while others who were less thorough were less successful, or failed entirely. The treatment is recommended with confidence. (Bulletins 73 and 105).

Fig. 58. Muskmelon leaf attacked by leaf blight. The dead spots are caused by a species of Alternaria. From Bulletin 73.

Root-Rot. (*Rhizoctonia*) The root diseases accompanied by rotting of the rootlets and induced by the sterile fungus of lettuce rosette is also found on greenhouse muskmelons. This is liable to be the case where these follow diseased crops of lettuce. The prevention is the same as that for the cucumbers, viz., thorough soil treatment.

Muskmelon Wilts are the same in general character as those described for the cucumber. Not only the bacterial wilt disease but the wilt due to fusarium has developed upon muskmelons in this state. The symptoms are the same as for cucumbers, namely: sudden wilting as from lack of water, followed by dying. The prevention treatment is the same as before recommended.

MUSTARDS

Black-Rot. Mustard plants of all species are liable to be attacked by black-rot and if permitted to grow as weeds in fields devoted to cabbage growing and will carry the black-rot trouble through the rotations in spite of the grower's other efforts. Let no mustard weeds survive in such rotations.

Club-Root. Mustard plants generally are attacked by the club-root fungus (*Plasmodiophora Brassicae* Wor.) when this is present in the soil. For this reason the weeds of several species may be infested upon lands that have never been brought under cultivation. Due attention should be given to mustard plants in new lands when designed for cabbage.

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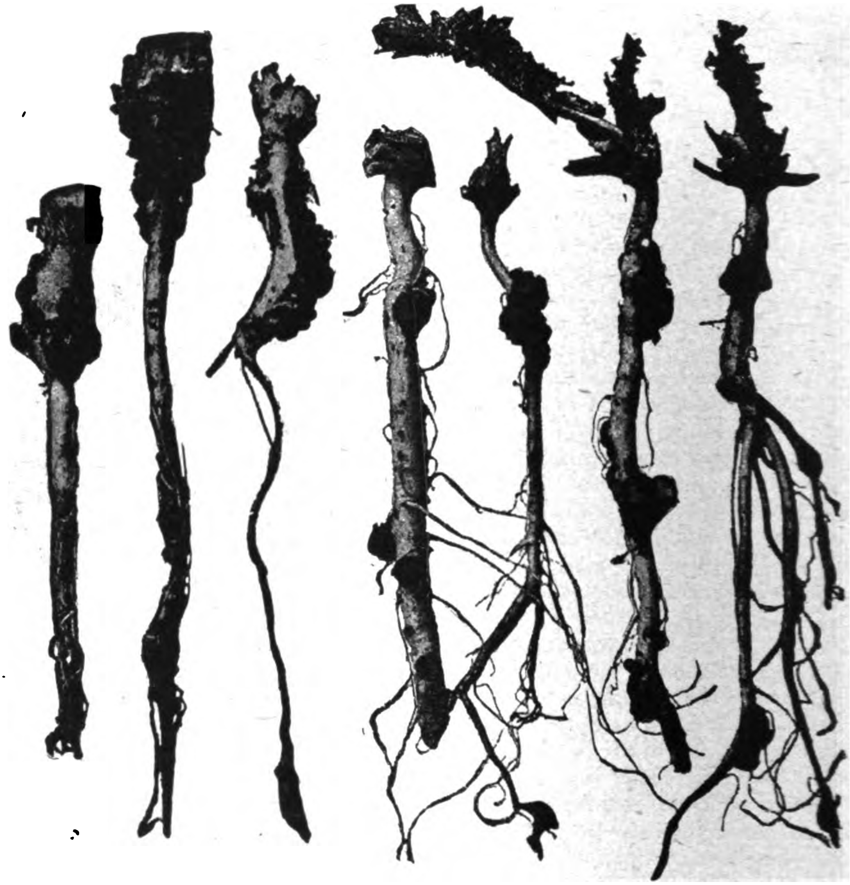

Figs. 59-60. Figure 59 on the left shows roots of shepherd's purse. Figure 60 on the right, roots of hedge mustard. Both are attacked by club-root. Both after Halsted. Bulletin 98, N. J. Exp. Sta.

Downy Mildew. The downy mildew fungus of crucifers (*Peronospora parasitica* (Pers. (De By.) is so universal on plants of the mustard family that it may be usually expected. The weedy species may accordingly keep up the supply of the parasite which attacks cabbage and cauliflower as well as others of the family.

Wilt. It is very necessary that search be made as to the survival of the fusarium of cabbage wilt on mustard weeds.

OAK

Anthracnose. The oak leaves are attacked by the same anthracnose fungus as attacks the leaves in young shoots of sycamore and maple, but this is not so prevalent upon oaks in Ohio as upon the sycamore.

TIMBER ROTS

Wound or Timber Rots of oaks are as yet imperfectly studied and call for thorough investigation before many statements can be made for us.

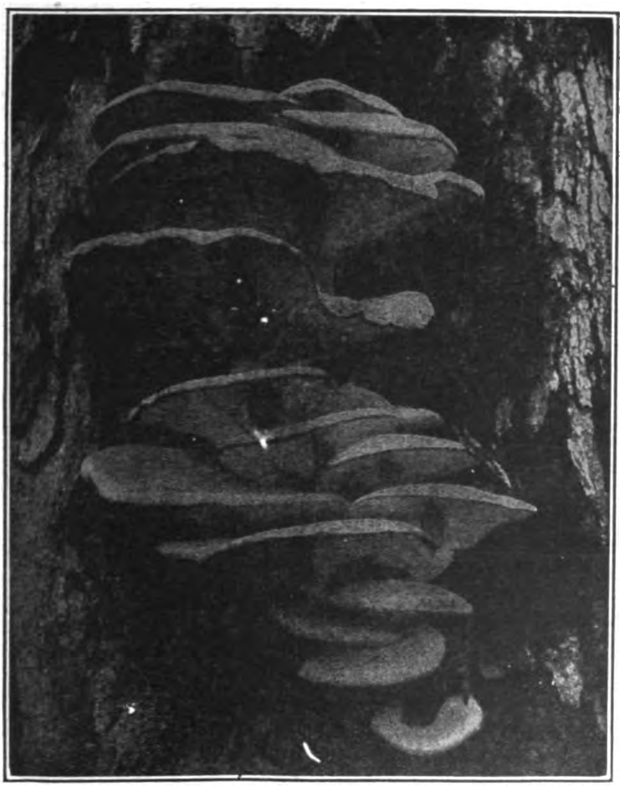

Fig. 61. A wound parasite (*Pleurotus ulmarius*) on the trunk of a maple tree. (After Freeman, Minnesota Plant Diseases).

OATS

Anthracnose (*Colletotrichum cereale* Manns.) is a new disease of oats which attacks the roots and basal portions of the culms together with the lower sheaths. The attack may extend even further than has yet been determined. The spores of this fungus were found adhering to seed oats of the crop of 1907 and the outbreak of the disease was studied in 1908. It shows by the development of the characteristic dark masses or acervulæ of the anthracnose fungus upon the lower joints of the stem, portions of the root and leaf sheaths.

The amount of loss resulting from it is liable to be variable since it acts by general reduction of vigor and reduced filling of the grain head. Treatment with formalin as for smut will certainly kill the adhering spores on seed oats. (See bulletin 203).

Blade Blight. A disease similar to that earlier described as bacterial disease of oats (see Journal of Mycology, VI; 72) has been very serious in Ohio during the seasons of 1907 and 1908. The phenomena are those of yellowing and dying of older leaves associated in most cases with the presence of an abundance of leaf sucking insects such as aphids, mites and leaf hoppers. Recent culture and colonizing studies made at the Station show the disease to be due to two specific bacteria working together. (*Bacillus avenæ* Manns.) (*Pseudomonas avenæ* Manns). These have been isolated and described. These bacteria are carried or transmitted by the insects or are scattered by natural agencies. In control work in cages the organisms caused infection through the punctures of the aphids (green flies). Evidently the control of this disease will involve thorough seed treatment together with possible field checking of the insects distributed. (See bulletin 210).

Rust. In addition to the two species of rust found upon wheat and to be given under that grain, there is a rust common upon oats (*Puccinia coronata* Corda.), usually prevalent during the rainy harvest weather and more or less at all times. No remedy is as yet at hand.

The Scab Fungus of the oats (*Fusarium roseum* Lk.) is the same species as for wheat and attacks the panicles near filling time. It results in empty hulls with the pink fungus. The disease also survives apparently as an internal infection of oat kernels and is capable of destroying young seedlings after the manner described for wheat. (See diseases transmitted in the seed and also wheat). Like that disease in wheat, it must be controlled, if at all, by a combination of seed treatment for adhering spores and thorough seed recleaning to exclude all light kernels.

Fig. 62. Head or panicle of oats destroyed by loose smut. All the oats kernels and many of their surrounding parts have been converted into black, soot (smutty) masses by the loose smut fungus *Ustilago*.

Smut. The smut of oats takes on two forms, the loose smut (*Ustilago Avenae* Jens.) and the hidden smut (*Ustilago Avenae laevis* (Jens.) Kell. & Swing). The first, which is the more common, converts the entire head, including glumes, into a sooty mass of smut spores (Fig. 62); while in the hidden smut the enclosing glumes remain about the smutted grain. No other essential difference has been found between them. Both are caused by spores from smutted seed, or seed from smutted grain, and both are successfully prevented by seed treatment with hot water or formalin as per scheme given elsewhere. (See calendar and also Bulletins 64 and 97). An increase of yield beyond smut prevention has usually followed seed treatment. This alone pays for the cost of treatment and the saving from smut loss is clear profit.

OAT-GRASS

Anthracnose. The same anthracnose fungus (*Colletotrichum cereale* Manns.) before described as attacking blue-grass, chess, oats, wheat, rye, etc., also occurs upon oat-grass. It is less liable to cause serious injury here than on the cereal grains.

Smut. There has been at the Station a smut on tall oat-grass (*Arrhenatherum elatius* L.) which closely resembles loose smut of oats but is, in fact, a separate species of smut whose mycelium survives in the rootstocks of the oat-grass (*Ustilago perennans* Rostrup.). The smut is thus continued in the same plants from year to year. It is not clear whether the smut would be transmitted in new seed, but there is some danger, at least.

ONION

Bacterial Disease. See heart-rot below.

Blight. Leaf blight or scald of onions during mid-season, when the weather is warm and dry, is rather a common occurrence. This was especially noticable during 1898 and 1899. While often attributable to insects, species of fungi, especially molds (*Macrosporium Sarcinula parasiticum* (B.) Thüm—*M. Porri* Ell.) were abundant in the seasons named. It may be possible to check these molds by spraying.

Fusarium Blight. This is often serious on young onions in old soil and is the forerunner of heavy losses from soft rot in storage.

Downy Mildew (*Peronospora Schleideniana* D'By.) is likely to occur upon onions, although it has not been seen in Ohio by the writer. The treatment would be as for downy mildew of other plants.

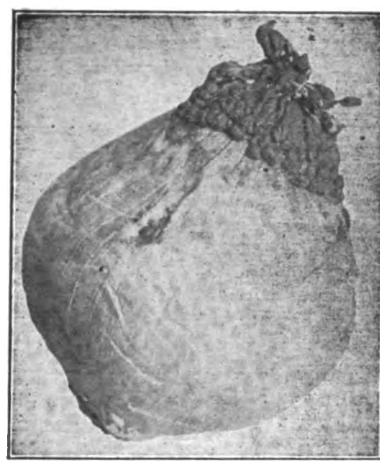

Fig. 63. A white onion that has been destroyed by a blackneck or dry-rot fungus, *Sclerotium cepivorum* Berk. This parasite has entered the onion through the green neck which was cut off at the time of harvesting the crop. (From a photograph by T. F. Manns).

Dry or Black Neck-Rot is the most serious disease of white onions in Ohio since the losses are so very large from it, particularly in Hardin County. The white onions are grown for somewhat special markets and it is the custom, at present, to gather early before the tops fall over, to top at once, and put up in crates in order to preserve the white color of the onion. As a rule this is not practiced with black, red and yellow sorts, so that this neck or dry-rot is not so common with them. Preliminary investigations have been made of this trouble and it appears to be clearly different from the smudge fungus which also disfigures the exterior of white onions. The fungus of dry-rot or black-neck (*Sclerotium cepivorum* Berk.) requires further investigation. (See Sorauer Pflanzenkrankheiten third edition, II 302-3). In Ohio onion districts the losses are very serious between the gathering of the white onions and time for winter storage while the crates are piled in buildings or in covered ricks in fields.

It appears at this time that the early topping of the white onions, leaving a green neck, offers an inviting way for the disease to enter; that the invasion is in this direction appears from the sclerotia of the fungus which forms in this region. (See illustrations). The disease appears to grow worse with continuous cropping of onions and the losses have recently been so large in storage as to render storage of white onions unprofitable. It has been suggested by this department that the white onions should be gathered and ricked in crates at once, either in buildings or covered with tent or temporary enclosure of building paper and disinfected or treated with formaldehyde gas as per the spray calendar. (See formula elsewhere). The enclosure should not be opened for 24 to 48 hours after treatment. In this manner it is hoped to keep down the infection of the white onions as well as of any others from similar troubles.

Heart-Rot. (Bacterial). This disease has been under investigation and appears to come in all varieties of onions, following the topping, by its rapid invasion of the center of the bulb through bacterial infection. It should be controlled by attention to disinfection of the topping machine or to similar treatment to that recommended for dry-rot. This disease ends in the complete destruction of the bulbs through a soft rot diferent from that described under soft-rot.

Fig. 64. Onion spotted by the smudge fungus. This fungus becomes very bad in land where successive crops of onions are grown. The fungus is also a factor in causing dry-rot of onions and set onions.

Smudge. This fungus (*Vermicularia circinans* Berk.) develops as a superficial spotting upon the exterior, especially attacking the white varieties; it is really an anthracnose of onions. For some time, because of its coincident development with the black neck or dry-rot, these two troubles have been confused. It is now apparently clear that there is no connection between the two, although this fungus causes dry rotting of sets and bulbs. The smudge fungus is cumulatively worse on old land where onions are grown consecutively. Apparently also in addition to rotation of crops the formalin drip treatment described under smut gives good results in keeping down this fungus. In field experiments made heretofore, the onions have been lost in storage from the dry-rot and the smudge disease has not been studied very fully in storage; apart from this it is believed to have little or no connection with the commoner storage rots, although the disfiguring effects of badly spotted onions reduce their market value, and rotting does take place as a result of it. The illustrations give characteristic appearances of these compared with healthy onions.

Onion Smut, on the other hand, is prevalent to a considerable extent in Ohio and is one of the most destructive of the smut fungi known to pathologists. This onion smut (*Urocystis Cepulae* Frost) unlike the other smuts with which we have to do, propagates itself almost indefinitely in the soil when this once becomes infested. Whenever a new crop of onions is grown from seed in this infested soil the smut attacks the young seedling onions, in whole or in part, and a very considerable loss results therefrom. If, however, onions sets are put in such soil, or seedling onions that have been started under glass in healthy soil are transplanted to smut infected soil, the smut fungus cannot attack them. The explanation seems to be that the smut threads are only able to penetrate the leaves of the young, tender seedlings. This onion smut is now known to occur in fields at Berea Perry, Madison and near Chillicothe. At the latter place it has seriously embarrassed some of the growers of onions for sets; for this work transplanting is, of course, out of the question. In Connecticut Experiment Station Report for 1889, it is stated that flowers of sulfur have been used to sow with the seed in infested soil, and this remedy has given but slightly inferior results to any other yet tried at this Station. Forty percent formalhyde, known commercially also as formalin, has given better results than sulfur in 1900.

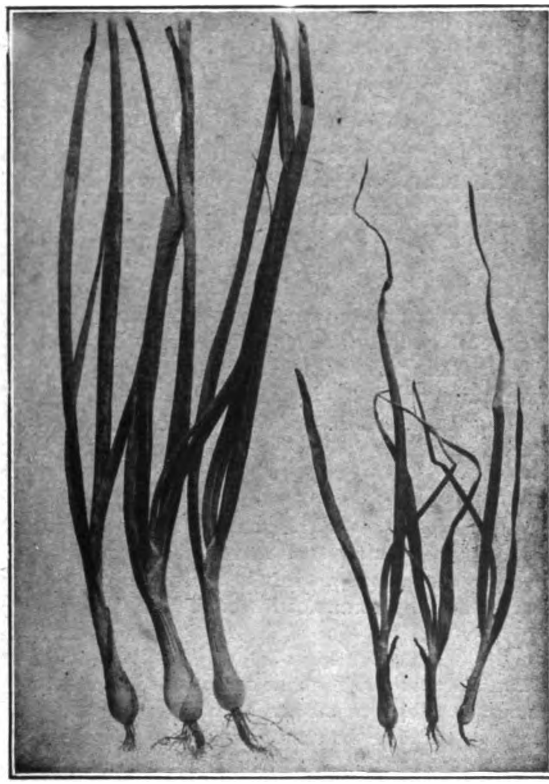

Fig. 63. Sound and smutted onions, gathered in midsummer The healthy onions were grown on badly diseased soil by the use of Formalin Drip treatment.—From a photograph by T. F. Manns.

At Berea, Chillicothe and latterly at Madison, experiments have been conducted to determine a practicable field method for smut prevention. The best method has proved to be that of formaldehyde drip with seeder. (See bulletin 131). The formaldehyde solution is made at the rate of one pound of 40% formaldehyde to 25 to 33 gallons of water. This is applied with drip attachment on seed drill at rate of 125 to 150 gallons per acre for field onions. The same results can be obtained in open furrows by applying solution with sprinkler after seeds are scattered until well moistened. This formalin treatment insures the disinfection of a layer of soil near the seed and permits the germination and the early growth, of the seedling onion, past infection stage, before the smut fungus can again occupy this soil. The gains from this treatment, both in the onion set work and in field onions are very large, amount-

ing to 100% to 200% increase. This method has recently been applied successfully in the Connecticut Valley by a representative of the United States Department of Agriculture.

Soft-Rot and Storage Rots. The Assistant Botanist has recently studied a soft-rot (*Fusarium* sp.) of onions which shows in field, but more seriously in subsequent storage. This soft-rot is produced by the fungus Fusarium, yet under study. It not only causes an early blight but also invades the onion bulbs quite rapidly after storage infection. The problems of control are essentially those of storage rots including dry-rot.

In onion storage it seems to the writer probable that disinfection of the onions after placing in storage buildings either by sections or otherwise: using the formaldehyde gas treatment will give excellent and safe results. This needs yet to be worked out.

ORANGE

In greenhouses oranges are frequently grown and complaints come to us as to the troubles upon them. The chief of these troubles is a black mold (*Capnodium citri* Berk. & Desm.) on the foliage and at times upon the fruit. Spraying with fungicides has usually brought satisfactory results and develops no special injury to orange foliage.

Fruit Rots. Orange rots in stored fruits are often brought to our attention, but do not properly belong to our state work. They are the result of mold attacks following bruising. The blue mold fungus (*Penicillium glaucum* Link.) and the green mold fungus (*Penicillium digitatum* (Fr.) Sacc) are both common. These are described in other publications. (See Bul. 8, Bureau of Vegetable Pathology, United States Department of Agriculture, also Bul. 184; Calif. Exp. Sta.).

ORCHARD-GRASS

Anthracnose. Orchard-grass is attacked by the same anthracnose (*Colletotrichum cereale* Manns.) as attacks wheat, rye, oats, blue-grass and timothy. The development is shown in a similar way by the black masses of the fungus upon the basal portions of the culms and sheaths.

PALM

Leaf Diseases. Frequent complaint is made of palm leaf diseases in conservatories; the department has been able to study these but little and finds more often that they are the result of over-watering. Several diseases have been reported on palm leaves. Among these we have an anthracnose fungus (*Gloeosporium Allescheri* Bres.) of Kentia. Dr. Trelease has reported upon another fungus on Phoenix (*Exosporium palmivorum* Sacc.). This also attacks the leaves causing ultimate death. Another leaf disease is described from Europe upon Chamaerops (*Graphiola Phoenicis* (Mong.) Poit.). It is caused by a fungus which is not infrequent on the date palm. Sprays such as Bordeaux or Lysol are recommended for these palm leaf diesases.

PEA

Anthracnose. The anthracnose or pod-spot of the pea (*Ascochyta Pisi* Lib.) often develops into a serious blight of field peas grown for canneries. This was studied by the department and it was found that the anthracnose fungus infects the seed peas so that these when planted give diseased seedlings and the consequent loss of crop. (See Bul. 173). The illustrations will show how the fungus spots the pods and thus has an opportunity to enter the developing

seed peas. It was shown by spraying experiments with Bordeaux mixture that healthy seed peas may be grown. The growth of healthy peas for seeding disposes of the problem of anthracnose.

Leaf-Spot. Other leaf-spots besides those of the anthracnose are sometimes found upon the pea and are apparently caused by another fungus (*Septoria Pisi* West.) These, if giving trouble, will be controlled by the spraying for anthracnose.

Powdery Mildew (*Erysiphe communis* Wallr.) The mildew fungus often attacks the pea and at times entirely destroys its fruitfulness. It may be known by the whitish coating produced upon the leaves and by the dark, pin-head spots of the fungus observed to be situated in these white coverings. The same fungus likewise attacks the bean. For either plant spraying with Bordeaux mixture, as per directions in calendar, will be found beneficial. The first applications should be made promptly.

Wilt. A wilt of pea, apparently allied to that of cow pea ond other forage crops of the south has been referred to a species of fungus *Neocosmospora* (*Fusarium*). As yet it has not been especially studied in Ohio.

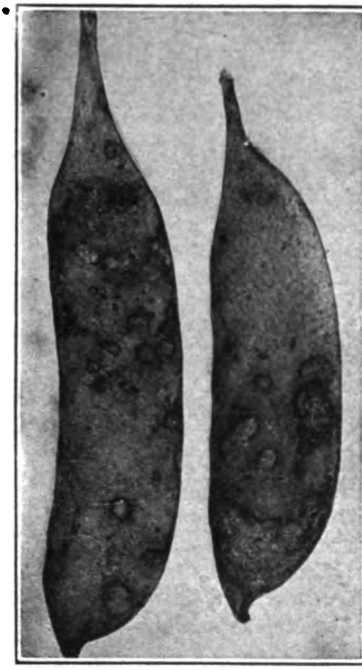

Fig. 66. Pods of French June field pea spotted by anthracnose. After Van Hook, Bulletin 173.

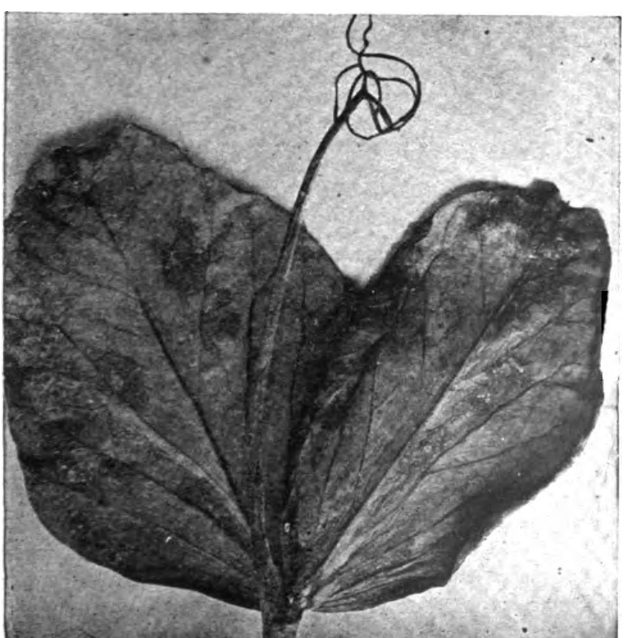

Fig. 67. Leaves of pea showing spots caused by anthracnose fungus-slightly magnified. After Van Hook. Bulletin 173.

PEACH

Anthracnose. An anthracnose fungus (*Gloeosporium laeticolor* Berk.) has been described upon the fruit of peach and has been found in Ohio, though rarely. Careful spray treatment as for scab should be successful against this disease.

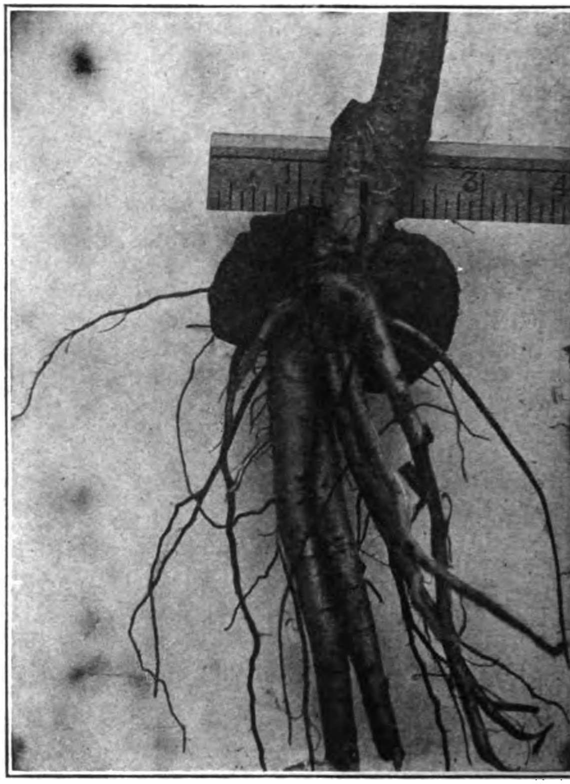

Fig. 68. Root of nursery peach tree attacked by crown gall.

Crown Gall. This is a very contagious disease of the peach and of other plants, notably daisy, raspberry, and blackberry, due to a bacterium (*Bacterium tumefaciens*) Sometimes it produces excrescences and enlargements upon the root and branches of the affected plant. More commonly the galls are found upon the stems just below the surface of the earth. These vary in size and in location, even occurring upon the small roots, and less frequently upon the stem at some distance above the ground. In some recent experiments (Bulletin 104) it was found that the gall trouble became communicated from diseased raspberries to peach trees set in the plantation. In some instances the loss from crown gall has been large and there is, in my judgement, no other disease common to several of our fruit trees that is so threatening in its ravages. The peach trees attacked in most cases perish without producing fruit. This applies when the trees are affected at nursery age—the usual condition. Purchasers cannot afford to set such diseased trees nor nurserymen to ship them. As yet the only treatment that we can recommend is to dig out and burn the diseased trees, and to avoid planting affected stock. Indeed no affected stock should be received. This, with other diseases, has been treated in Bulletins 92 and 104.

Fig. 69. Crown gall attacking stem of peach tree.

Frosty Mildew. Occassionally the frosty mildew fungus (*Cercosporella persicæ* Sacc.) occurs, whitening over the under surface of the leaves. As yet it has not been a serious disease.

Gum-Flow. The gum-flow diseases of the peach are frequent but have, as yet, been imperfectly studied in our state. We have no distinct gummosis, although in some varieties of peaches it would seem this is a weakness or a form of injury due to climate followed by gum exudations. Bark borer injuries produce a well-marked gum-flow.

June Drop is often named by peach growers as a specific trouble. It consists in the dropping of the young peaches during the month of June, though dropping sometimes comes earlier. The cause seems to be physiological and need not be feared where the trees have been prevented from overbearing, or protected from the effects of drought by thorough cultivation the previous season.

Little Peach is a disease much discussed in Michigan and is quite serious in the fact that the peaches on diseased trees never come to proper maturity or develop marketable character. Dr. Smith has found that the root hairs on many such trees are not healthy and thus it appears that some specific trouble is located there.

Leaf-Curl (*Exoascus deformans* B.). The leaf-curl fungus is at times one of the serious pests of the peach grower. However, destructive leaf-curl does not occur every year. The curl fungus survives as mycelium in the buds from year to year. It is therefore present each season, though possibly in varying amount.

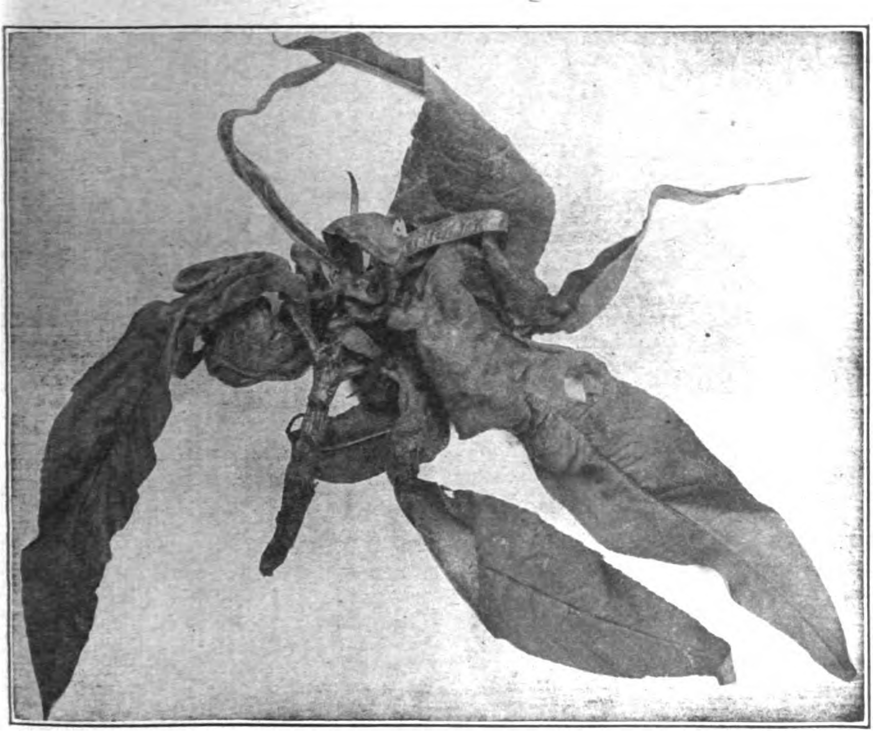

Fig. 70. Leaves of peach attacked by leaf-curl. The attack of the fungus causes rapid cell multiplication and results in the distorted shapes. From a photograph.

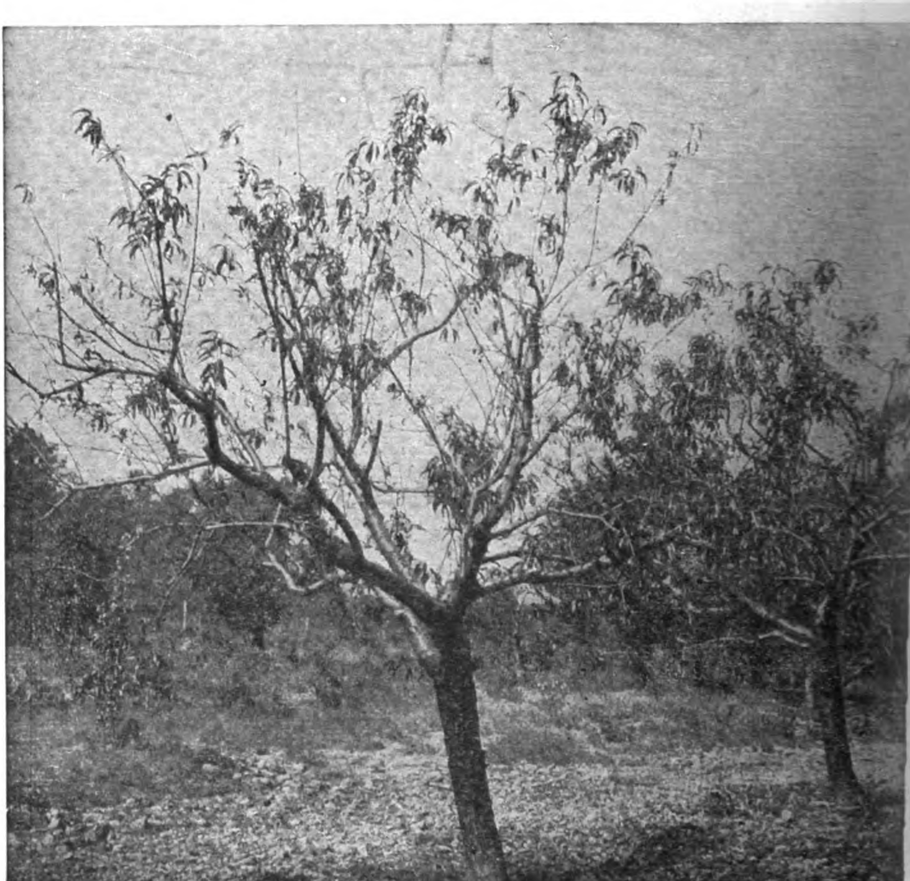

Fig. 71. Eleven-year-old Elberta peach tree, unsprayed, defoliated by leaf-curl. No fruit. From Bulletin 148.

Fig. 72. Eleven-year-old Elberta peach tree, sprayed, March and April, 1903, with soda-lime-sulfur-vitriol, under direction of the owner. Foliage and fruit crop saved by the treatment. From Bulletin 148.

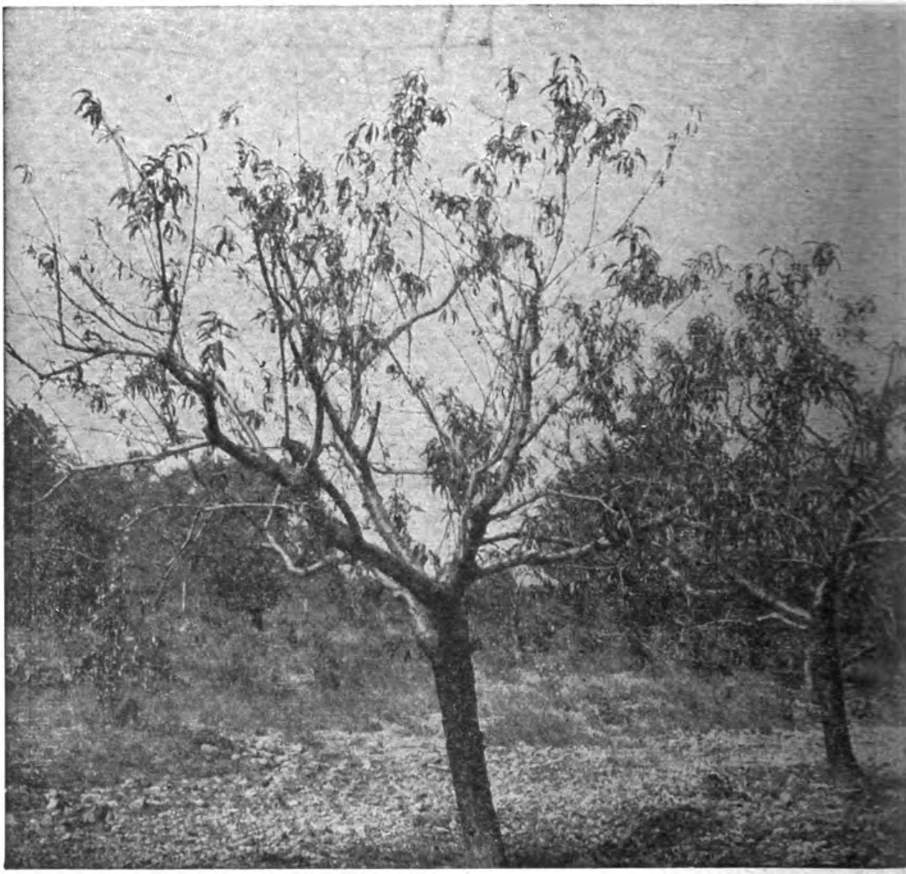

Fig. 71. Eleven-year-old Elberta peach tree, unsprayed, defoliated by leaf-curl. No fruit. From Bulletin 148.

Fig. 72. Eleven-year-old Elberta peach tree, sprayed, March and April, 1903, with soda-lime-sulfur-vitriol, under direction of the owner. Foliage and fruit crop saved by the treatment. From Bulletin 148.

We have found in Ohio that serious leaf-curl comes when cool weather, with frequent rains, prevails during April, May and June. It is to the April weather that the most serious trouble seems attributable. With low temperatures and frequent rains during the early half of this month we may safely predict an outbreak of leaf-curl (Bulletin 92). During such weather the fungus develops rapidly and the new leaves are affected as they are protruded from the bud. In a modified sense the same takes place during May and in a still more limited sense during June. Successful prevention of leaf-curl is secured by thorough early treatment with Bordeaux mixture. Indeed, it appears that a spraying at any time shortly before the blossoms open is several times more effective than any application afterwards. It appears that more effective results are secured by spraying two weeks before blossoming than immediately before the blossoms open. In any event an application made just before the blossoms open is more effective than at any later date. Lime-sulfur applications for scale insects are effective to prevent leaf-curl. Whale-oil soap has also proved effective applied at this time, though not safe at much earlier dates. It is more expensive than Bordeaux mixture. (See Bulletins 104 and 148).

Leaf-Spot of the peach may be due to a variety of causes and in no cases studied have they proved destructive. One fungus (*Cercosperella persioe* Sacc.) is often mentioned. These leaf-spot are illustrated and very briefly discussed in Bulletin 92.

Pustular Spot of the peach is a disease referable to a minute fungus (*Helminthosporium carpophilum* Lev.) which is apparently spread by spores that alight upon the upper surface of the fruit, flourish there and produce minute, light-brown spots, often surrounded by an angry red border. The red border is conspicuous in earlier varieties and is sometimes elevated and pustular in appearance. This fungus greatly disfigures the fruit and is very easily prevented. Three applications of Bordeaux mixture have reduced the amount of pustular spot to less than one percent; whereas unsprayed trees gave more than sixteen percent of spotted fruit, much of which was seriously damaged. (Bulletin 92).

Powdery Mildew (*Sphaerotheca pannosa* (Wallr.) Lev.) sometimes attacks peach in our state, but rarely with serious results. The attacked leaves sometimes turn white and are sometimes distorted. Spraying with potassium sulfid or self-boiled lime-sulfur would be successful.

Rot or Brown-Rot. The brown-rot fungus (*Sclerotinia* (*Monilia*) *fructigena* (Pers.) Schroet) is among the most destructive of the fungi on the peach, yielding place only at times to leaf-curl. Unlike leaf-curl the brown-rot prevails during warm, showery weather, and with such a weather period is likely to occur at any time of the year. In April, if the mummy peaches are permitted to remain on the trees from the preceding year, the fungus may affect the twigs through the blossoms and thus cause serious twig blight. It is a matter of common remark that the branches upon which rotted peaches are found often perish from the effects of the rot fungus. The survival of the fungus in these "mummy" fruits and the production of ascospores from them are well proven. No one variety seems more susceptible to rot than others, although some sorts are more liable to ripen during rainy weather and then rot worse. The

Fig. 73. Rotted and dried or mummy peaches collected on trees in spring. These mummies will produce growth of the rot fungus with showery, warm weather. They are dangerous.

control of rot demands: First, careful removal and destruction of all mummy rotted peaches in which the fungus survives; Second, thorough spraying of the trees before blossoming, as for leaf-curl; Third, subsequent spray treatment with self-boiled lime-sulfur as per calendar, may be profitable under certain conditions.

Root-Rot. In some instances, notably at Gypsum, Ohio, where peach trees were planted in a dense, clay soil, the roots often decay, apparently from the attacks of some fungus. Trees thus attacked usually perish soon. Whether the trouble is primarily due to the fungus or to the location in which the trees are grown has not been determined.

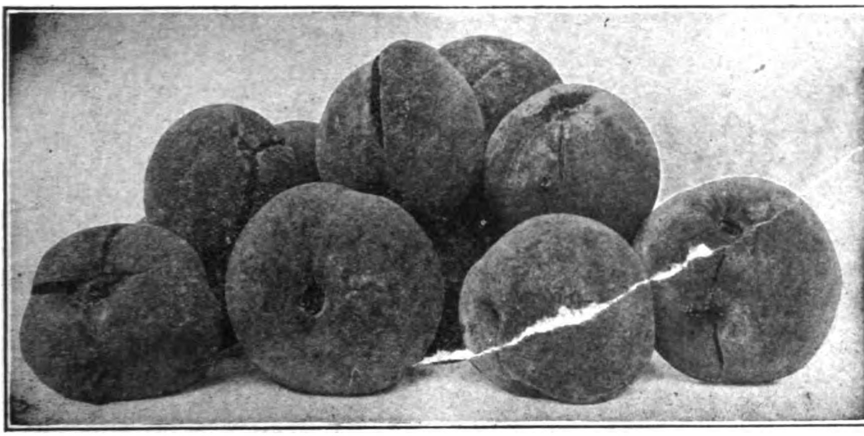

Fig. 74. Peaches of the Salway variety with one side blackened and cracked from scab. This loss is prevented by proper spraying.—From Bulletin 148.

Another root-rot has been further studied and found to be prevalent where orchards are set in newly cleared land, if following growths of oaks. The attack upon the roots show the rhizomorphs of the root-rot fungus as in apple root-rot which has later been more often noted in the west.

Rust. A rust fungus occurs upon the peach but not to a serious extent in Ohio.

Scab or Black-Spot. This fungus (*Cladosporium carpophilum* Thum.) is a serious drawback in the growth of certain varieties which seem susceptible. These are Morris, White, Salway and some other late sorts. It causes dark spots upon the fruit followed by cracking and entrance of the rot fungus with serious results. To control this disease, spraying results reported in bulletins 104 and 148 obtained by the use of dilute Bordeaux mixture were very satisfactory, but secured with some injury to peach foliage. In 1908-9 studies were made in an orchard near Brownhelm where self-boiled lime-sulfur was tested in comparison with dilute Bordeaux mixture. The results are very promising and indicate that self-boiled lime-sulfur is the remedy to be applied at intervals of two to three weeks after foliage appears.

Stem Blight. A stem blight of the peach was studied several years ago by the writer. (See bulletin 92). It is due to a specific fungus which in this instance attacked the stems of nursery stock causing a constriction, and this is

in line with the effects of the fungus described from Europe as a constriction or lacing disease. While in the case studied there was loss of nursery stock, due possibly to some injury to which it was exposed, there has been little recent trouble. Infection may surely be prevented by treatment with fungicides.

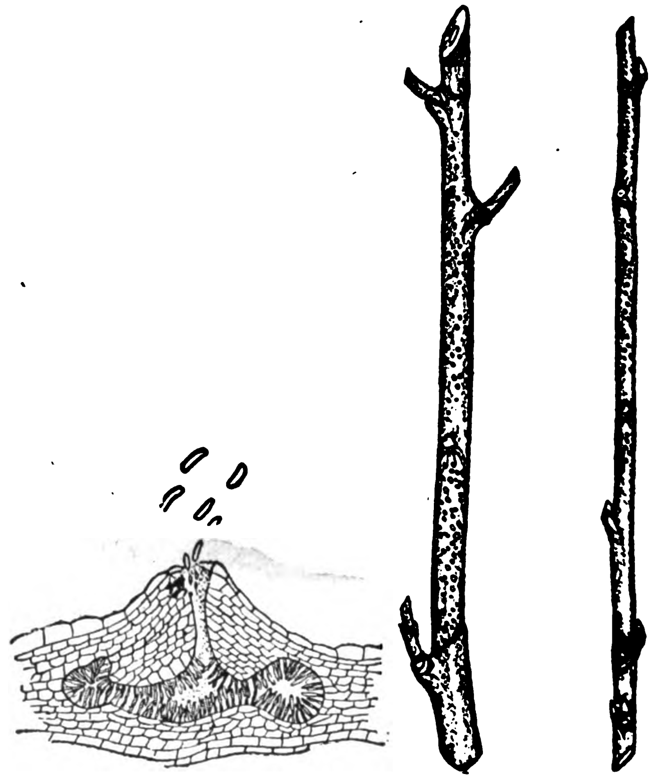

Fig. 75. Stems of nursery peach trees attacked by Constriction fungus. (*Phoma persicae* Sacc.). The trouble causes dying out of the diseased parts of the stems which are shrunken where attacked. The detail structure of spores and pycnidia are shown magnified about 500 diameters.—From Bulletin 92.

Winter Injury. In our climate the severe freezing of winter often injures the trunk and branches of peach trees. The common killing back of new growth by freezing is a familiar phenomenon. The common killing of the trunk on one side, usually the west or southwest, is also known. Many instances have been studied. Wherever there has been late growth of the trees, followed by severe winter cold, such injury may be expected. Late cultivation is therefore to be avoided. Winter injury to fruit trees may be attributed to the drying out of the trees and it is worth while to consider whether by mulching, or soil conditions, the tree may not be made to have an abundant supply of available moisture, when the upper soil is frozen hard. Much injury to peach trees from freezing occurred during February, 1899, and in the fall and winter of 1906-7. In the larger portion of these earlier cases there was more water in the soil, or about the trees, than in the less injured localities. More exposed situations also gave more injured trees. In 1906-7 the freezing was sudden upon unripened wood. (See Bulletin 192.)

Fig. 76. Peach tree, two years old, Carpenter, Ohio—one of those remaining alive though injured by freezing of 1906-7. Dead branches and ridge on trunk mark dead portion. From Bulletin 192.

Yellows. Peach yellows is a serious, contagious disease of this fruit in most portions of Ohio. Only in certain seasons may we find yellowish color as a marked symptom of affected trees. The true symptoms of yellows are: 1. Premature ripening of the fruit which is highly colored, often purplish spotted, and has the flesh marbled with red. 2. The premature growth of winter buds, resulting in excessive branching on new shoots, and the development of slender, wiry branched twigs. 3. Resting buds or adventitious buds are formed on the trunk and branches; these grow into sickly shoots with pale, narrowed leaves, and usually become much branched, with tips like veritable brooms. Aside from these specific evidences of yellows which serve to distinguish yellow color from true yellows disease, there are others less easily described but none the less useful to the practical observer. This disease may be recognized late in the

season by the late, adventitious growth. The sources of disease are diseased trees or affected nursery stock, more often the former. The remedy is to remove and to burn the yellows trees, root and branch, on the spot where found. Dragging diseased branches may spread yellows and all such trees are a menace. To leave an open hole over winter and replant the next year is a safe practice. (See Bulletins 72 and 92 for fuller discussion).

Fig. 77. Peach Yellows, winter buds of diseased tree unfolding in autumn. (After Smith, Farmers' Bul. 17, U. S. Dept. Agric.)

Recent investigations of this disease show that it is due to an enzyme which converts the leaf chloryphyll into a diseased form, causing yellows conditions. It is doubtless this enzyme which is transmitted, as in the case of tobacco, by actual contact. These discoveries have changed in no way our method of handling the disease. (See enzymatic diseases in introduction).

Rosette of peach is a disease of the southern states which appears to be similar in cause and transmission to peach yellows.

PEAR

Anthracnose. An anthracnose fungus (*Colletotrichum* sp.) occurs upon the fruit of the pear in the east, but has not been seen in Ohio.

Black-Rot (*Sphaeropsis malorum* Pk.) of the pear is the name applied to the rot like that of the quince and apple and due to the same organism. While it is less frequent as a source of fruit rot upon the pear, it is present both in this form and in the form of branch attacks or cankers.

Pear Blight or Fire Blight is one of the most serious drawbacks to pear growing. The symptoms of dead twigs and branches are well known. In substance our knowledge of pear blight is about this:—It is due to a bacterium (*Bacillus amylovorus* (Burr.) which, in the old cases of blight, winters over in the blighted parts. With April and May showers there is some exudation of watery substance from these parts, containing the zoogloa masses of the bacterium; when visited by insects these are by them transmitted to the opening blossoms. The microbe there breeds in the nectar of the blossom and in that manner attacks the branches; once within the tissues the microbe may spread indefinitely. Some varieties of pears are more susceptible, apparently, than others, which simply means that in them the microbes spread more rapidly. There is not a single variety of blight-free pear in our region. The remedy consists in cutting off and burning the blighted parts each autumn, extending the work to the crab-apple, apple and indeed to every variety of pome fruit which is attacked by this bacterium. In recent years Mr. Wm. Miller, of Ottawa County, has reported better results in blight control since he practices thorough spraying of the trees in early spring with lime-sulfur. (Bulletin 79. Year-book U. S. Dept. of Agric. 1895).

Fig. 78. Crown Gall on end of pear root.

Crown Gall. The crown gall attacks the pear both at the crown and upon tips of roots. It is less rapid in its destructive effects here than upon the peach, though but slightly less serious. Enlargements may be readily detected and they are usually of denser, woody growth than upon the peach. The same remedies apply here as with that fruit.

Leaf Blight of the pear is produced by the leaf blight fungus (*Entomosporium maculatum* Lev.) which causes spotting and dying of the leaves, also cracking of fruit. The diseased leaves show a dense, dark colored coating on the under side. This disease is readily and successfully prevented by the use of Bordeaux mixture as a spray.

Leaf-Spot of pear is another fungus disease which may flourish despite the use of Bordeaux mixture, as generally applied. This fungus (*Septoria piricola* Sacc.) appears not to yield to the standard fungicides. It produces small, circular dead spots in the leaves; the spots in later summer may drop out, leaving holes. It is quite prevalent, but as yet no specific recommendations can be made for it.

Pear Scab is a fungus disease allied to Apple Scab; the pear scab fungus (*Fusicladium pirinum* (Lib.)Fuckl.) being very similar in development to that of apple scab. This fungus was very abundant in 1898. It may cause spotting of the leaves or spotting of the fruit of the pear but is not readily distinguished from the other troubles save by the use of the microscope. It is prevented by the use of Bordeaux mixture.

Rust. The development of the early form of the cedar rust sometimes occurs upon pear as upon apple.

Sun-Scald is the name applied at times to the trunk injuries upon pear which are more commonly but the work of the pear blight bacterium at such points.

Sooty Disease. A sooty disease of pear fruit like that which occurs upon apple (see pages 372-3) likewise occurs upon the fruit and is also controlled by similar treatment.

PELARGONIUM

Dropsy. Some varieties of cultivated pelargonium, possibly called begonia, suffer seriously from dropsy. One bright scarlet flowered variety in particular has been cultivated at the Station. It often suffers from dead spots in the leaves. Before these spots in the leaves die, examination will show that there are wet looking places upon the under side of the leaf which appear translucent when held between the observer and the light. These are nothing more than leafcells which have become so gorged with water as to be ruptured. The break down extends to adjoining parts and then tends to produce the spots before described. This is purely a physiological trouble due to excess of water. The remedy is clear. Withhold water until absolutely necessary.

PEONY

Stem-Rot—Wilt. Frequent complaint comes to us of the dying of the stems of peony. The writer has had similar trouble. The disease has not been fully investigated. Massee and others have identified a rot fungus(*Botrytis* (*Sclerotinia*) *paeoniae* Oud.) to which more or less of the stem rot may possibily be referred. The symptoms are a gradual dying of the leaves. Examination shows stems to be rotted near the ground or often very much higher. A strong, insoluble fungicide might be successfully sprayed upon the stems without covering the leaves.

PEPPERS

Anthracnose. Two anthracnoses of peppers have been described from New Jersey, as occurring upon the leaves of the plants (*Gloeosporium piperatum* (E. & E.) (*Colletotrichum nigrum* (Ells. & Hals.) although the latter may at times be found upon fruits. In addition to these Dr. Halsted has demonstrated that cultures of the apple bitter-rot as well as the bean anthracnose, will flourish upon fruits of pepper.

PERSIMMON

Leaf Diseases. So far as known to the writer no strictly fruit diseases of the persimmon occur in our district. We may have at least three leaf diseases. These are an anthracnose fungus (*Gloeosporium diospyri* (E. & E.), the true leaf-spot fungus (*Cercospora atra* (E. & E.) and a powdery mildew (*Podosphaera oxyacanthae* (DC) De By.). The mildew will show like others, as a whitish covering upon the leaves, while the others are likely to inflict real injury to the leaf tissues. All should be possibly controlled by spraying.

PHLOX

Leaf-Spot. Cultivated phlox is frequently attacked by a leaf-spot fungus (*Septoria divaricatae* E. & E.). This mars the appearance of the leaves but is not often serious.

Powdery Mildew. There is a powdery mildew fungus also (*Erysiphe Cichoracearum* DC) sometimes found upon cultivated phlox. It develops as a whitish covering over the leaves and other parts. Both should yield to spraying properly done.

PINE

Damping-Off. A damping-off fungus (*Fusarium* sp.) has recently been very troublesome with seedlings of white pine in the east. This has been investigated and remedies have been tried successfully. These are either dilute sulfuric acid or powdered copper sulfate and lime; the former being sprayed on the seedlings about the base and the latter applied as dust. (See Cir. 4, Bur. Plant Indus.). It is likely that with efforts to grow white pine for timber purposes in this state, troubles of this type will not be restricted to this parasite.

Leaf Blight and Leaf-Spot. Leaf troubles have been met in most areas where white pine grows naturally or is being cultivated very largely. One of these so-called leaf blights is referred to a fungus, (*Septoria parasitica* Hartig). It has been found in adjoining states if not in Ohio. Another leaf-spot fungus (*Phoma strobi* Berk and Br.) is quite prevalent upon white pine in Eu pe. It is believed that this parasite or a closely related one, (*Phoma strobilinum* P. C.) occurs within our borders. Remedies have yet to be worked out for these troubles.

Root-Rots are to be expected in addition to the damping-off fungus before mentioned, especially among seedling pines under culture.

Rust. In Europe the blister rust fungus (*Cronartium ribicolum* Dietr. *Peridermium strobi* Kleb.) has been long known as a serious drawback to the culture of the white pine. Curiously enough this rust has until recently not been known in the United States. Not long since warning was sent out by the Department of Agriculture that this rust had appeared in America and should be sought for upon its alternate hosts, the white pine (Aecidia) and the currant and gooseberry. (Uredo- and Teleutospores). Upon the pine the aecidial stage develops numerous orange cluster cups infecting the stem toward the base. This causes high mortality among the young pines. Upon the currant and gooseberry the uredospores show yellow color which darkens as the teleutospores form. These are to be sought in August or early September, and by reason of the importance of this rust merit early attention by students of these diseases.

PLUM

Black-Knot. This is the same disease as that described under black-knot of cherry. It is more frequent upon the Damson than upon the other European plums, but requires only the removal and burning of the knots each year before March, in order to grow plums successfully and without serious injury from this disease.

Fig. 79. Cluster of plums destroyed by rot causing "mummies." "Mummy" plums are dangerous whether left upon the tree or dropped to the ground, since they carry the rot fungus over the winter period.

Brown-Rot is by all odds the most serious disease with which Ohio plum growers have to deal, outranking by far black-knot, shot-hole fungus and all the other ills plums are heir to. It is the same in character as the rot of other stone fruits. As with the peach, the rot fungus (*Sclorotinia* (*Monilia*) *fructigena* (Pers.) lives over winter in the mummy rotted plums of the year before and possibly, to a limited extent, in affected branches. The first step in successful control of rot is the removal and burning of these old plums. The next step is to spray thoroughly, before the buds open, and to continue the spraying and picking the rotted plums as circumstances demand. Likewise,

control the curculio. For details of treatment see calendar. No halfway measures will yield satisfactory results in dealing with plum rot.

Cankers. In Europe trunks of the plum as well as trunks of forest trees suffer from canker caused by a distinct species of fungus. As yet we have no true proof of cankers due to these parasites in Ohio. The parasite is *Nectria ditissima.*

Crown Gall. This disease has been reported upon the plum as upon the peach, but is less frequent.

Fig. 80. Plum leaf attacked by Shot-hole Fungus. This fungus is the same as that causing Leaf-Spot on cherry, but in this case the diseased areas of the leaf tend to drop out, leaving "shot-holes."

Leaf-curl. On Japanese varieties of plum, the leaves at times suffer from leaf-curl attacks similar to those upon peach. It should be reached by the same remedy, winter sprays.

Mildew. The powdery mildew fungus of the cherry (*Podosphaera oxyacanthae* (DC) De By) also occurs at times upon the plum, but is usually rather easy to control.

Pockets or Bladders. American varieties of plum are sometimes attacked by a fungus (*Exoascus* sp.) related to the leaf-curl fungus. This causes enlargement of the young fruits which are hollow; because of this condition they are sometimes alluded to as "bladders." The conditions which bring about the disease are the same as those of leaf-curl, viz., excessive cool wet weather in the early season. The winter spray as for leaf-curl should be effective.

Root-Rot. Plums are susceptible to attack of root-rot as in the case of other orchard fruits where set following timber or fruit trees that have suffered.

Shot-Hole Fungus is at times a very destructive disease of the plum. It is due to the same fungus (*Cylindrosporium Padi* Karst.) which attacks the cherry, although in this case even more serious injury is liable to result than with cherry trees. Where trees are defoliated by shot-hole fungus the fruit is of small value and the trees put forth new foliage and blossoms, thus leaving immature wood and a sappy condition for trouble in winter. Under such circumstances the secondary losses may be enormous. This fungus is readily prevented by spraying with standard Bordeaux mixture, the first application being made when the leaves are half grown, and two more at intervals of about three weeks.

Winter Injury or so-called Sun-Scald. In 1896-7, following neglected cases of shot-hole fungus which defoliated the trees in the fall of '96, some plum orchards were almost totally destroyed by the severe winter freezing. The sappy trees were not in condition to withstand the severe cold,— 15 degrees. Young trees were killed to the snow line while older trees had the sides of the trunk, commonly that facing to the southwest, severely injured. Plum trees were again injured by freezing in 1906-7. (See Bulletin 192). The prevention of this trouble lies in the prevention of the shot-hole fungus and the avoidance of the conditions named. In some cases it is possible that protection of the trunk by straw or boards might be profitable.

Rust upon the plum has been collected in some of the western states, but at present has not been seen in Ohio by the writer.

POPLAR

Anthracnose. Species of poplar or cottonwood are at times attacked by anthracnose (*Marsonia populi* Hals.). It produces similar effects to those of anthracnose upon sycamore.

Rust. The leaves of poplars are frequently attacked by the rust (*Melampsora populina* (Jacq.) Lev.) which disfigures the leaves by the spots caused through its development. The thrifty growth of poplars usually overcomes these foliage diseases under favorable conditions.

POTATO

Bacterial Blight. This is a serious disease of the potato; it also attacks the tomato, tobacco and egg-plant. It has been referred to a microbe (*Bacterium solanacearum* Smith). The parts of the stem attacked die off suddenly and the tubers from the affected plants have a dark discoloration of the tissues in a distinct ring at a slight distance from the exterior of the potato. Fungicides are practically useless for this disease. Such diseased tubers should not be planted nor should potatoes follow a diseased crop of tomatoes, egg-plants or potatoes. (Div. Veg. Path. B. No. 12, U. S. Dept. of Agric.)

Black-Leg. In much of Europe and in America the bases of potato stems are often attacked in the early season by a basal stem-rot which causes serious check to the growth of the plants. The diseased parts show well-marked lesions due to the work of a bacterium (*Bacillus phytophthorus* Appel.). Dr. Smith has recently investigated the disease in this country and has found it widely distributed. In Ohio it occurs to a certain extent and is at times quite similar in its effects to those referred to rosette. Measures of control will largely consist in rotation of the potato crop. See Bulletin Maine Expt. Station 174 (1909).

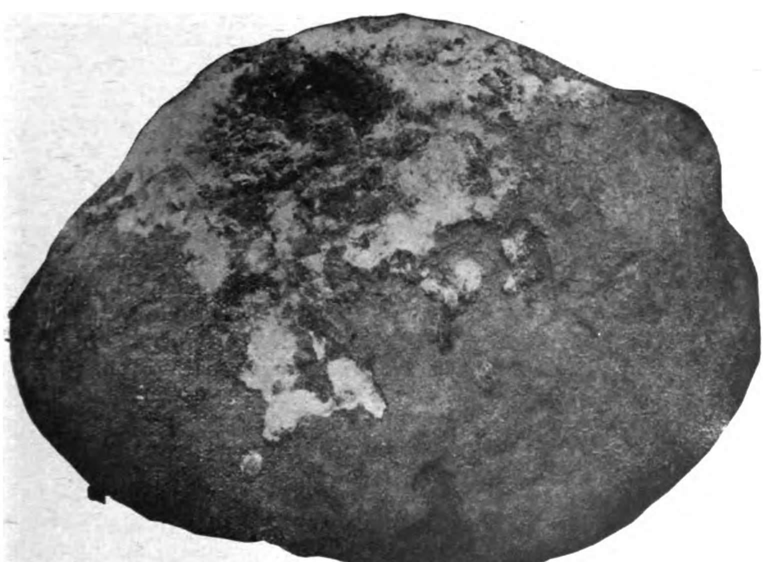

Fig. 81. A potato destroyed by Dry-Rot. This shows the characteristic appearance of the rotted potato.—From a photograph by T. F. Manns.

Dry-Rot. The dry-rot fungus (*Fusarium oxysporum* Schl.) has become generally prevalent in Ohio. This attacks the plant as the result of seed tuber or soil infection, causing wilt troubles of the plants (see Fusarium Blight) as well as dry-rotting of the tubers in storage. This tuber dry-rot is shown by the mold-like development of the fungus on the tubers. All such tubers should be rejected and rotation in potato growing should be practiced. Partly infected lots of potatoes held in storage should be promptly used. The infection of seed tubers is shown by cross sections near the stem end of the tuber at digging time or later. Where infection occurs there will be browning of the vessels near the exterior of the potato. In limited infection only small spots will show, but as the infection advances these brown tissues show as characteristic rings approaching that in bacterial blight. These spotted tissues yield the fusarium of infection in cultures as has recently been shown by the assistant botanist. Since we know that this parasite develops as a blight of the plant proper, we need to reject all diseased tubers for seed. (See Fusarium Blight).

Fig. 82. Early Blight on potato leaf. (After Jones).

Early Blight of potato is a premature spotting and dying of the potato leaves, due to the work of a parasitic fungus (*Alternaria solani* (E. & M.) Jones & Grant). The occurrence of the early blight, however, is liable to be influenced by the general vigor and other conditions of the plant; yet there is no just basis for denying, in the light of our present knowledge, the parasitic nature of this disease. Jones has made cultures of the fungus and produced the disease by inoculation (Vt. Exp. Sta. Buls. 24 and 28; Rept. 1892) and has secured most admirable results by the use of fungicides. This successful spraying in itself is in the nature of proof of parasitic character. In the potato work at this Station it has been the uniform practice to spray thoroughly with Bordeaux mixture, adding arsenites for the insects, as required, and it has been many years since we have suffered any serious loss from early blight. However, the spraying for early blight will not prevent the bacterial disease above described, and it is doubtless the confusion of these two diseases that has led to such differences of opinion among potato growers as to the efficiency of spraying with Bordeaux mixture for early blight. There is real danger of the confusion of early blight with the Fusarium blight described in the following paragraph Our recommendation is still that contained in the spray calender, namely: to spray with Bordeaux mixture or some modified form of it.

Fusarium Blight. Early in the season of 1909 it was discovered that a small area of one of the unfertilized potato plots at the Station was dying out. Subsequently the area became larger and investigation showed the fungus to be that of dry-rot, which see. Later it developed that the yield of the entire tier of plots grown in three crop rotation, died prematurely although spraying had been practiced as usual. The dying plants showed infection and the dead areas had

in them black masses of a species of fungus (*Vermicularia*) whose relation to the disease is undetermined. At digging time it was found that in addition to grub injury, the tubers were very generally infected with the markings of the dry-rot fungus in the conducting tissues. Sections of the stem end showed brownish discolorations of the vessels, and occasionally tubers showed marked invasion by the fungus. Tubers collected elsewhere sometimes showed these discolorations of the vessels extending half the length of the tuber. Injury by grubs favored infection.

Following these discoveries quite thorough studies were made of potato conditions in the state, and it developed that the fusarium blight prevailed in local fields throughout the entire potato growing area. While some growers had obtained fine crops in spite of limited infection other growers had suffered seriously.

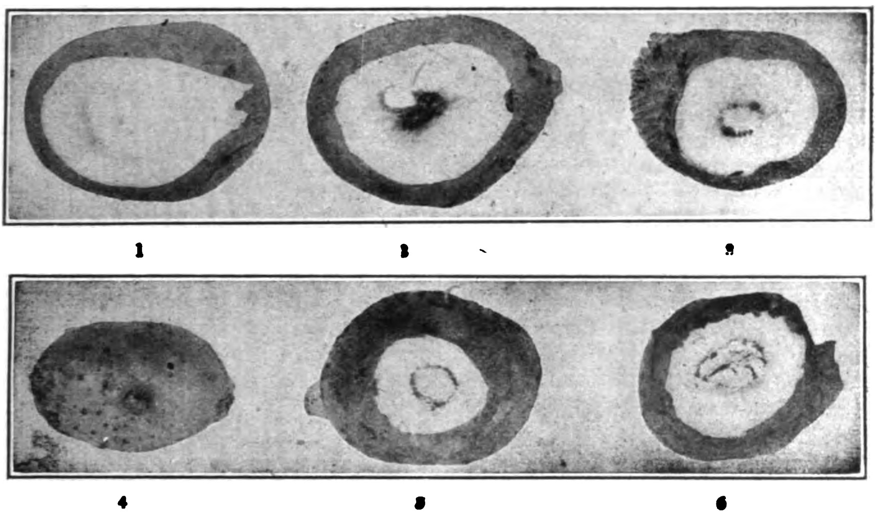

Fig. 83. Potato tubers attacked by Dry-Rot Fusarium, showing sections near the stem-end of healthy (No. 1) infected potato tubers. (Nos. 2-4) This infection may be easily discovered by cross sections made with a sharp knife, and sections from sterilized tubers give cultures in Petri dishes. At times the discolorations extend to the middle of the tuber.)From a photograph by T. F. Manns).

One grower in Summit county, who had succeeded very well in 1908 had such serious loss of crop from fusarium blight that he was led to attribute it to spray injury since blighting and dying went on in spite of the spray treatment. Investigation showed that his entire area was very badly infected with this fusarium. He was advised of the fact and warned against using infected seed or immediate planting of infected land. It developed also that northern grown seed showed up quite satisfactorily. On further examination it developed that the seed from Red River Valley and from parts of New York and possibly parts of Michigan was nearly free from infection by this fungus. It was also developed that seed potatoes stored in cellars have sometimes given much less satisfactory return than seed from the same field stored in outdoor pits. This would seem to be explained by the known fact that (*Fusarium oxysporum*) the dry-rot fungus, makes slow progress at low temperatures, that is 42° or below. This disease presents a real problem in potato growing for the year of 1910, and interpreting the results of 1908 in light of the experiences of 1909, one is led to infer that the disease then prevailed and accounted in part for the general early dying of potato tops.

In Europe, especially in Germany, in 1907 and possibly in the seasons since much complaint has been made of a similar disease to that described by Stewart as a leaf-roll disease (*Blattrollkrankheit*). In the European disease as well as in the stem blight of potatoes described by Stewart in New York (See Bulls. 101 and 138) and in our present fusarium blight, the leaves of the affected plants lose color and roll upward from the border. With this occurs a general loss of green in the plants. Orton, who has made a general study of the disease throughout the country, regards the fusarium of dry-rot as the causal organism, and finds very serious checks upon potato growing have resulted in San Joaquin county, California, upon so-called tule lands where continuous cropping in potatoes has been more or less practiced. The evidence is conclusive that we have in the dry-rot organism a blight organism of the potato plant which is at the same time a soil infesting as well as a seed tuber infecting fungus. In addition to this, incomplete observations support the idea that some spread of the organism takes place as with other fungus parasites in the field. In the matter of preventive measures and remedies, the first consideration should be given to seed tubers. These should be of such source and character as are clear from infection. This infection may easily be determined by cutting across the stem end of the tubers. Evidently cellar stored seed is dangerous during this period of epidemic. In the matter of spray prevention we have evidence in a cooperative test in Portage County, that the spray holds back the advance of the development. Upon duplicate plots where strong Bordeaux mixture was used, the gain was at the rate of 13 bushels per acre above any other sprayed plots; and 9 bushels per acre above the checks. These plots remained green longer than any of the others and show a decided reaction to the copper fungicide. From the behavior of certain hills in the various fields whose tops remained green in spite of the general infection, breeding for blight resistance should give decisive results.

Late Blight or Rot of the Potato (*Phytophthora infestans* De By) called in Europe "the potato disease" is caused by a downy mildew fungus. This mildew spots the leaves, producing a downy, felt-like covering in spots on the under side of the leaves of infested plants. This causes prompt dying with wet-rot conditions of the leaves and the tubers are rapidly destroyed with wet-rot appearances. The potato Phytophthora is a disease which like its host plant is accustomed to somewhat cooler conditions of climate than usually prevail in Ohio. However, in the years 1904 to 1907 all the summer months were several degrees below the normal; this resulted in continuous out-breaks of the blight or rot, culminating in 1906-7. In 1908 under warmer or drier conditions while the fungus was found at Wooster it did not inflict damage here or elsewhere in the state. It is unlikely to be injurious in Ohio, except in seasons cooler and more moist than normal. (See table of seasons page 354).

Spraying for late blight is entirely successful and should begin by the 20th of July, being repeated at intervals of two weeks and applications made at the rate of 100 gallons per acre on full grown vines. The duration of the spraying will depend upon the maturity of the plants, in the late crops reaching four or occasionally five sprayings.

Rosette. The Rosette or Rhizoctonia disease often prevails in Ohio, especially where potatoes are grown on acid soils. This acid condition is evidently favorable to the fungus which attacks the stems of the young plants or even in early developments of the stems, these are often rotted off below the surface for the earth. In later developments the elongation of the plant axis is stopped and a rosette appearance is shown in the leaves. The disease survives by the red-

Fig. 84. Showing a plant of potato affected with Rosette. The elongated injury below the soil surface shows as dark-colored in the figure.—From Bulletin 139.

brown sclerotia upon the seed tubers; these are largely controlled by seed treatment with formaldehyde or corrosive sublimate. (See bulletins 139 and 145).

Potato Scab is a well known parasitic disease of the potato tuber that needs no extended description. Whether due to fungi or bacteria, or both, the practical prevention of potato scab consists in destroying the parasites on the seed potatoes and then in planting them in soil free from those organisms. The organisms in question will usually be found in soil on which potatoes were grown the previous year, or in that freshly manured. The materials used by this Station in treating for scab are two, namely, solution of corrosive sublimate and solution of formalin, as per strengths given in spray calendar. It is ineffective to treat the seed and then plant on scab-infested land. See also Wart-disease.

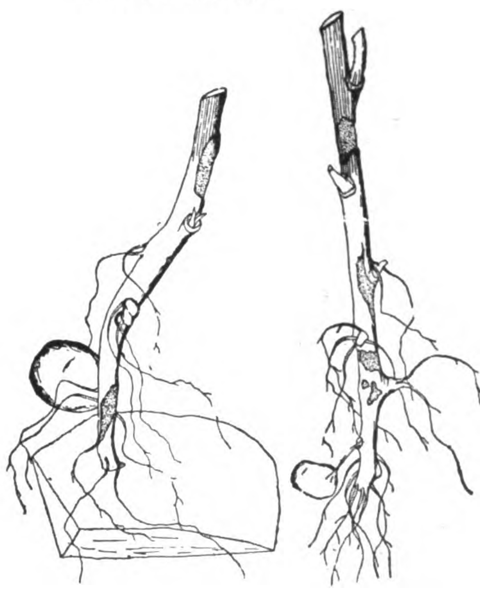

Fig. 85. Bases of potato stems showing lesions caused by Rosette Fungus. The shaded areas were dark with an abundance of the fungus, and the tops showed conspicuous Rosette effects. From Bulletin 139.

Tip-burn. Potato leaves often show dead margins or tips even where no parasitic attack can be discovered. Such "tip-burn" effects may also be increased by any extra weather stress as of drouth or by spray injury. These conditions are to be met by avoiding the causes which bring them about.

Wart-Disease. This disease, also called "canker" and "black-scab" is caused by a soil infesting fungus, (*Chrysophlyctis endobiotica* Schilb) and has recently become established in New Foundland and possibly at other points in North

America. It was discovered upon potatoes from upper Hungary in 1896 and has since become distributed over much of northern Europe including Germany, England, Ireland, Scotland and Wales. Apparently this wart disease is the most serious potato trouble yet met with in cultivation, since it causes large warts upon potatoes but partially infected and converts those badly attacked into corky masses not unlike lumps of coke. Such tubers are entirely unfit for human food though they may be used for stock food after cooking. The fungus causing the disease survives in the potato by resting spores as well as by its vegetative parts and appears to remain as a soil infestation for five to six years. Seed treatment is not effective in controlling the disease. Every effort should be made to secure the exclusion of the disease from the United States and to recognize it should imported tubers carry the trouble. See Güssow, Bulletin 63 Central Experimental Farms (Ottawa) and Orton, Circular 52, Bureau Plant Industry 1910.

PRIMULA

Rot. A rot of Chinese primula due to Botrytis and similar to that on peony has been reported and may be expected with us.

PRIVET

Anthracnose. Privet in hedges is frequently attacked by anthracnose (*Gloeosporium cingulatum* Atk.). This shows itself by lesions in the younger stems and results in dying of the portions of the attacked branches beyond the lesions. This weakens the hedge and sometimes results in secondary consequences. While spraying has not been fully worked out for this disease, it should prove an effective remedy at the proper time.

PUMPKIN

Downy Mildew and Wilt attack pumpkins after the manner described under muskmelon and cucumber. The remedies are the same as there stated.

QUINCE

Anthracnose. The fruits and possibly the branches of quince are attacked by an anthracnose fungus (*Glomerella rufomaculans* Sp. & V. Schr.) which is the same as that causing bitter-rot in apple. According to our knowledge of the survival of this fungus, attention must be given to gathering and burning of "mummy" fruits and to the cankers produced, if any, upon the branches. The spraying treatment necessary is the same as that for apple bitter-rot.

Black-Rot. The fruit and foliage of the quince are attacked by black-rot. The black-rot multiplies very rapidly in the fruit of quince and often causes loss of much of that produced. This fungus (*Sphaeropsis malorum* Pk.) also develops as a leaf-spot upon the foliage causing defoliation. It is liable to attack the branches after the manner determined for apple. To hold this fungus in check very careful spraying is required at times, but as a rule it is easier to keep down the black-rot on fruit and foliage of quince than to keep it down on susceptible apples. The spray used is Bordeaux mixture.

Leaf-Spot of another kind which is identical with that upon pear is found at times formed upon the quince. It is controlled by the same treatment as the black-rot.

Blight. The blight upon quince (*Bacillus amylovorus* (Burr.) De Toni.) is slightly less destructive than that upon pear. It is caused by the same bacterium and requires the same watchful care and attention as in the case of pear.

Pale-Rot. This (*Phoma cydoniae* Sacc.) is reported from some of our states and may occur in Ohio. There is no evidence to indicate that it will require more prolonged treatment than black-rot or leaf-spot.

Rust (*Gymnosporangium* sp.) also occurs upon the quince when trees are near cedars which carry the cedar apples and distribute spores. Labor must be devoted to the destruction of the source of infection as in the apple.

RADISH

Black-Rot, Club-Root. Black-rot (*Bacterium campestre* (Pamm) and club-root (*Plasmodiophora brassicae* Wor.) occur upon the radish at times and are of the same nature and cause as these diseases upon other mustards, especially cabbage and cauliflower. The attention to control will be similar to that for cabbage.

Downy Mildew and White Mold (*Peronospora parasitica* De By. and *Cystopus candidus* Pers.) also occur upon the leaves of radish, the latter more especially upon younger plants. These are the same diseases that have been described upon other mustard growths.

RAPE

Black-Rot, Club-Root, etc. Rape, as other mustards, is attacked by a group of diseases which are common upon plants of the mustard family. These are black-rot, club root, white mold, etc., that are more fully described under cabbage, cauliflower and radish.

RASPBERRY

Anthracnose (*Colletotrichum venetum* (Speg.) Hals.). The anthracnose fungus is a frequent bane to the raspberry grower. It attacks the young canes and so spots and injures them, as well as the foliage, that when the time arrives for ripening the fruit the plants are unable to do this and the crop is largely lost. The Horticulturist of this Station has always succeeded in holding this disease in check by use of the methods of spraying recommended in the calendar for anthracnose. Care, however, must be used in the application of the spray to reach the stems of the young canes and to keep the fungicide from the leaves of bearing canes where it will do injury.

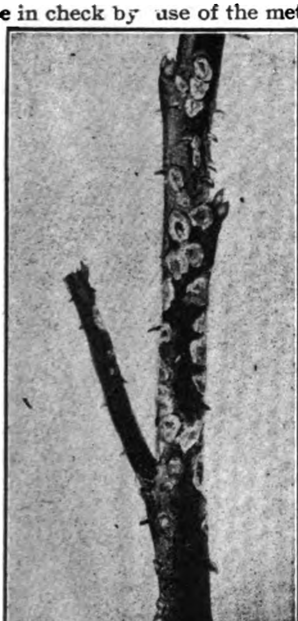

Fig. 86. Raspberry stem attacked by Anthracnose. This causes "birds-eye" spots of the stems. After Scribner.

Cane Blight. Serious dying of raspberry canes has occured in some of the northern districts where they are largely grown. These troubles range from "dieback" to impaired vigor in which there are seeming brown patches upon the stems. As a rule these have failed to yield a specific organism and may be the result of root conditions which appear to be quite unsatisfactory on both raspberry and blackberry, as described under the former.

Crown Gall is at present one of the most destructive diseases attacking raspberries. In some well marked cases upon the variety known as Thompson's Prolific (Bulletin 79) eel-worms have been suggested as the possible cause of the gall production;

Fig. 87. Crown-Gall on raspberry plants. These also occur on the roots.

but whatever the cause of the galls attacking that variety we have found them transmitted to the peach in the same soil and we have found that practically all of the varieties of raspberries are attacked by a similar trouble producing like excrescences. These galls result in the destruction of the bearing canes, and where the raspberries are planted in orchards the disease, it would seem, may extend to the orchard trees as well. Late investigations show that a bacterium is the cause of crown gall on the almond. (Science N. S. Vol. XXIII, No. 575, pp. 424, 425; by Erwin F. Smith, U. S. Dept. of Agric.). Prompt removal and burning of all affected canes is the only method of treatment. Indeed it has been demonstrated from the very beginning that a healthy raspberry plantation cannot be secured by the selection of apparently healthy plants from diseased areas. Nothing remains but to secure plants from healthy plantations.

Bacterial Blight of raspberries has been described by this Station; it has not recently proved serious. (Bulletin 78).

Leaf-Spot and Rust. The leaf-spot fungus, already described for blackberries and dewberries, upon which it is more commonly found, was prevalent in 1899 upon raspberries. The only remedy for rust (*Caeoma nitens* Schw.) is the removal and destruction of all clumps either wholly or partially infected. The leaf-spot fungus (*Septoria rubi* West.) will yield to spraying with Bordeaux mixture. Winter injury usually occurs and is shown by the killing back of canes which fail to mature properly. The remedy must lie in the avoidance of the conditions.

RED-TOP

Anthracnose (*Colletotrichum cereale* Manns.) was found upon red-top, as also upon timothy, orchard-grass, wheat, rye, oats and chess. The symptoms are the same as for the other grains; the disease attacks the culms and sheaths upon the lower part of the stem. The chief interest which comes from the disease upon grasses is the means this may serve to carry the disease of one rotation to the next in cereals.

ROSE

Anthracnose. An anthracnose fungus (*Gloeosporium rosae* (Hals.) attacks the rose, causing defoliation of the canes; indeed the whole plant is attacked. This behaves very similarly to the anthracnose fungus of the raspberry. Young plants are found most susceptible to the disease. The methods of handling are practically the same as for the anthracnose of the raspberry.

Crown Gall. Crown gall trouble essentially the same in character as that of raspberry, occurs on roses but requires no separate description here.

Leaf Blotch (*Actinonema Rosae* (Lib.) Fr.) often causes dark spotting of the leaves. The frost-like, branching growth over the leaf-surface is often very pretty in design though injurious in effect. If the rosehouse is too moist, or if other conditions be slightly unfavorable, the fungus seems to flourish all the better. It may be checked by the use of Bordeaux mixture or by dilute copper sulfate solution, as recommended for cucumbers in the greenhouse (One pound to fifty gallons).

Fig. 88. Branch of rose root with Nematode Galls.

Rose Mildew is attributed to the fungus (*Sphaerotheca pannosa* Lev.) which is commonly prevalent in rosehouses; it is also found occasionally out of doors. This mildew is, for the forcing house, largely diagnostic, indicating, when prevalent, uneven temperatures. Proper attention to the matter of heat is the best preventive. Sulfur is often sprinkled upon plants and is frequently used upon the steam pipes, but it is not clear that the influence is very great.

Nematodes. Among the most serious of the rose diseases is that caused by the eelworms or nematodes which attack the roots. As with cucumbers, these parasitic worms induce the growth of small bead-like galls upon the roots of the rose. The leaves dry up from the margins, the plants generally turning yellow and breaking down as the outcome of this interference with the proper work of the roots. This subject of nematodes is discussed at length in Bulletin 73. No successful remedy has been found for plants once attacked. The method of prevention consists, as in the case of cucumbers already cited, in the proper steaming and treatment of the soil designed for use in the rose benches.

Fig. 89. Head and upper portion of stem or rye attacked by anthracnose. The point of attack upon the head is shown by the removal of the glumes; that portion above died. Upon the stem the dark spots are the acervuli of the anthracnose. From Bulletin 203.

Rust (*Phragmidium subcorticium* Schrank.). This is occassionally met and proves very disfiguring. As yet we can advise nothing more than the choice of rust resistant sorts.

RUTABAGA

Rutabaga is attacked by the same diseases as attack turnips.

RYE

Rye Anthracnose. This new disease was very serious upon rye in 1908 and was surely prevalent in 1907. The spores are carried by adhering to the seed grain and can be discovered in centrifuge separations of grain washings. In rye fields the anthracnose attacks both the heads and the lower portions of the culms. The localized attack upon the head (rachis) kills all that portion of the spike above the point of attack and the grain is but partly developed. See Fig. 90. Upon the bases of the stems, including the roots, the fungus develops its dark masses often closely packed together and dotting both stem and sheaths (see figure). In 1908 the loss of yields in rye were from 25 to 60 percent of the total crop.

For control of the disease thorough separation of all the light rye kernels in the seed and subsequent seed treatment are recommended. (See Bulletin 203).

Fig. 90. On the left kernels of rye shriveled from an attack of anthracnose; on the right, normal, healthy kernels of rye. From Bulletin 203.

Ergot occurs occasionally in rye; the fungus (*Claviceps purpurea* (Fr.) Tul.) attacks the kernel and transforms it into a large club-shaped dark mass, the ergot of the druggist. The amount of ergot is usually not enough to be a serious trouble in our state. Ergotism in domestic animals is sometimes caused when diseased rye is fed to them.

Rust. The species of rust which occur upon wheat are also found upon rye. (See wheat).

Scab. The scab (*Fusarium roseum* Lk.) as is shown by recent work at this Station attacks rye almost as freely as wheat. The fungus in question is shown by recent work to be the same as that in wheat. The remedy is the same as that recommended for anthracnose.

Smut. The fungus (*Urocystis occulta* Wallr.) of stem and blade smut in rye occurred at this Station in 1909. It attacks the culms, leaves and leaf-sheaths but not commonly the floral parts. The smutted parts swell and burst open in elongated lines. Seed treatment may reduce this smut but hardly prevent it altogether.

SALSIFY

White Rust (*Albugo tragopogonis* Tul.) attacks this plant and is sometimes destructive. The best results seem to be promised by avoiding sources of infection and by spray treatment.

SORGHUM

Bacterial Blight of sorghum is somewhat similar in its general appearance to the bacterial blight of corn already described, and is caused by a specific organism (*Bacillus sorghi* Burr.). It has been described in the Kansas Experiment Station Report for 1888.

Grain Smut (*Cyntractia Sorghi-vulgaris* (Tul.) Clinton) attacks the seed of the sorghum plant. The hot water treatment may be adapted to prevent this.

Head Smut (*Sphacelotheca reiliana* (Kuhn) Clint.) occurs occasionally where sorghum is grown, but is less common than grain smut.

SOYBEAN

Wilt occurs in most districts where soybeans are grown. We have had very few reports in Ohio. Indications show that the one most likely to occur is that due to a wilt fungus (Fusarium).

SPINACH

Anthracnose occurs upon spinach but is not definitely known in our district.

Downy Mildew. The downy mildew fungus (*Peronospora effusa* (Lev.) Rabh.) is already known upon lamb's quarters and may appear upon the cultivated spinach of the same order. It shows as discolored or dead spots in the leaves with felted, downy covering underneath. Methods of prevention here would be as for cucumbers, except that applications could scarcely be made after the plants are nearly developed.

In older trucking districts other diseases such as white smut and scab have been reported, but are not known to occur with us in Ohio.

SNAP-DRAGON

Anthracnose. Stewart has described an anthracnose fungus of snap dragon (*Colletotrichum antirrhini* Stew.). This attacks the leaves causing brown spots and is at times serious. It may be successfully combatted by spraying with Bordeaux mixture.

Stem-Rot. A stem-rot (*Phoma* sp.) also attacks the stems of snap-dragon at any point above the ground. It is especially severe on the younger or sucker stems.

SQUASH

The squash is attacked by diseases already described under cucumber, namely, anthracnose, downy mildew and the wilts. The remedies are likewise the same.

SOLOMON'S SEAL

Leaf Diseases. Solomon's Seal is attacked by a fungus (*Aecidium convallariae* Schul.) which causes characteristic orange-colored cluster cups, and by a leaf-spot fungus (*Phyllosticta cruenta* (Kickx.). This latter disease is liable to give increasing trouble in culture.

Smut. Parts of this plant are also attacked by a smut fungus (*Urocystis colchici* (Schl.) Rabh.). I believe this is rather infrequent.

SPRUCE

Leaf-Spot. Norway spruce in Ohio has suffered seriously in 1908-9 from attacks by a leaf-spot fungus (*Phoma* sp.). This fungus causes the discoloration of the leaves (needles) also their dropping. The fruit bodies of the fungus occur upon the scales of the branches as well as upon the leaves and are evidently capable of surviving from year to year. This leaf-spot or leaf blight has been reported from several counties upon hedge plantings, upon large shade trees and upon sizes grown for Christmas trees. Drouth conditions in 1907 were a large factor in this matter causing the death of many spruce trees in 1907 and 1908. It is believed that winter and early summer sprayings will have some effect in checking the leaf trouble. This experience shows the need for mulches about Norway spruce, especially in the southern portion of Ohio.

Seedling diseases are liable to prove troublesome thus checking efforts to grow seedlings of spruce.

STRAWBERRY

Aborted Fruits. In certain seasons, and especially in 1908, there were many reports of misshapen and aborted fruits. In certain cases the salable fruit was less than 50 percent of the whole. These misshapen fruits are rarely the result of disease, more often they are the indirect result of imperfect pollination. The effects of weather conditions in hindering pollination and making it imperfect are well known. Some bright sunny weather is all essential.

Anthracnose (*Gloeosporium fragariae* Mont.) has been found upon strawberry leaves in other states; it has given less trouble than the other foliage diseases with us up to this time.

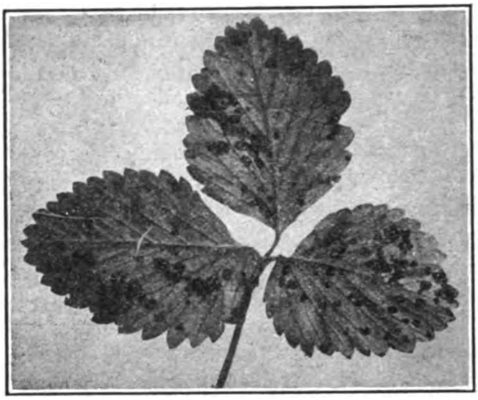

Fig. 91 Leaves of strawberry attacked by Leaf-Spot. The lighter centers have dark borders. This fungus forms ascospores in the strawberry leaves. From a photograph by T. F. Manns.

Leaf-Spot or Rust so-called is the most serious disease of older strawberry leaves. The leaf-spot fungus (*Sphaerella fragaria* (Tul.) Sacc.) matures in the old leaves. In the earlier spots on young leaves three forms of fungi are found, most of which are probably stages in the development of the leaf-spot fungus. This disease is essentially one of the season before the crop is injured. Spraying upon new plantations after picking any fruit present will usually be found profitable. The practice of burning over strawberry beds after picking to destroy old leaves and the fungi upon them, as well as possible insects, is based upon right principles and is commonly successful.

SUGAR BEET

Crown-Rot (*Phoma betae* Frank) has been discovered in most of the sugar beet growing states and is liable to be present in Ohio in the factory district.

Leaf-Spot. The sugar beet, which is beginning to be extensively cultivated with us, has been injured by the leaf-spot fungus (*Cercospora beticola* Sacc.) and by other diseases. The leaf-spot produces small, dead areas in the beet leaves, followed at times by dying of all the leaves. For this fungus Bordeaux mixture may be applied with confidence, at intervals of three weeks. The first application should be made when the plants are about 5 or 6 inches high.

Root-Rot occurs at times, particularly upon beet seedlings where planted in rich trucking soil. The fungus

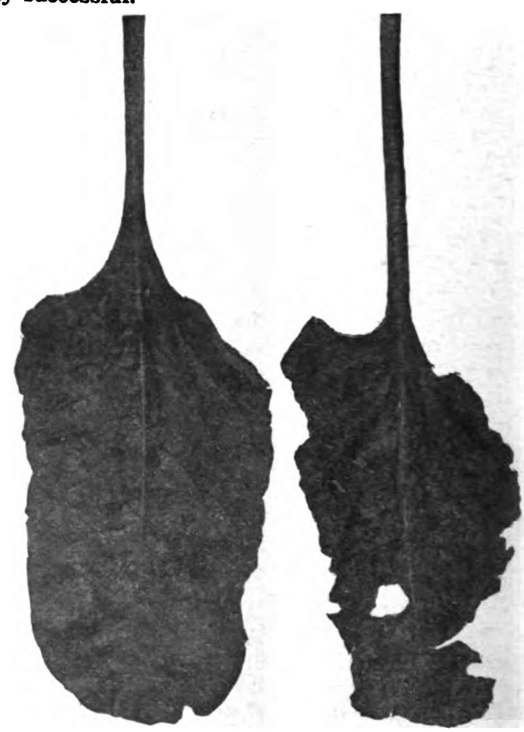

Fig. 92. Leaf-Spot trouble on sugar beet.

appears to be the same as that attacking the greenhouse seedlings of lettuce tomatoes, etc., (*Rhizoctonia* sp.) and can apparently be reached only by similar methods.

Beet Scab affects the roots of the beet as the scab does potato tubers. It is thought to be due to the same organisms. It may be avoided largely by avoiding the conditions for scab already mentioned under potato scab. Rotation of sugar beets will probably be required to escape this and other diseases.

SWEET POTATO

Bin or Soft-Rot is encountered by the sweet potato growers. The fungus (*Rhizopus nigricans* Ehrh.) producing it may be present in the plant bed and apparent as dark spots or rotted tips on the plants at setting. All such plants ought to be discarded if avoidance of disease is sought. Some experiments were made at Marietta in 1897, to prevent or reduce this rot, but without positive advantage in the keeping qualities. A dope or mixture of 6 parts earth to one part flowers of sulfur was dropped in handfuls and the plants set through the mixture thus bringing it about the roots of the plants very nicely. Smoother potatoes were obtained and these separated more readily from adherent earth, but no better keeping qualities resulted for that year. The potatoes were harvested, however, during a wet period and conditions were less favorable than is often the case.

Soil-Rot (*Acrocystis Batatas* Ell. & Hals.) is a serious disease of sweet potatoes for which the above described treatment has proved successful in New Jersey. (N. J. Exp. Sta. B. 126).

Stem-Rot (*Nectria Ipomoeae* Hals.) attacking the stems and roots has appeared in Ohio sweet potato fields, apparently introduced by affected seed. Such seed should be avoided. Rotation may also be necessary.

White Mold or White Rot (*Cystopus Ipomoea-panduranae* (Schw.) Farl.) is common upon the Man-of-the-earth and the wild morning glory (*Convolvulus hederaceae*) in the sweet potato districts, but apparently is not frequent upon sweet potato foliage.

Black-Rot. This disease of sweet potato roots shows in dark, somewhat greenish spots of varying diameter. It causes serious losses in the roots and rom diseased potatoes gives "black shank" in great abundance upon the young plants. The fungus (*Ceratocystis fimbriata* Ell. & Hals.) has been described as a result of Dr. Halsted's work in New Jersey. In treatment the measures are largely preventive in the choice of healthy seed, healthy sprouts and the sterilization of the plant beds.

SWEET CORN

Bacterial Disease has at times proved serious in sweet corn fields, but is apparently the same in character as that attacking sorghum, broom corn and field corn.

Smut (*Ustilago Zeae* Beckm.) also attacks sweet corn and where crops are grown consecutively in garden, the amount is sometimes excessive. The cause of it is the same as that of field corn and the conditions of control are the same.

SYCAMORE

Anthracnose (*Gloeosporium nervisequum* (Fckl.) Sacc.) is periodically very destructive on the foliage of the sycamore, extending at times to the younger shoots. The warm wet springs appear to be favorable to it; such was noticeably the case in 1908 and again in 1909. The outbreak in these years extended all over eastern United States. While the disease should be amenable to fungicides, it has been neglected.

Powdery Mildew. The leaves of the oriental sycamore, which is planted largely in Cleveland and other cities, are much disfigured by the powdery mildew fungus (*Microsphaera alni* (?). This was studied by the writer in Cleveland in 1909. It was found that younger trees were subject to attack by the mildew fungus late in the season, so that a foot or more of the tip of the shoot was disfigured by the mildew and many of the leaves were prevented from full development. The fungus does not complete its development early, and up to November 15th no spore sacs were formed. This leaves moderate doubt as to the exact identity of the fungus. It is hoped to hold this mildew in check by spraying which seems to be necessary on younger trees of the oriental sycamore.

TIMOTHY

Anthracnose (*Colletotrichum cereale* Manns)occurs upon timothy and as already noted on blue-grass, orchard-grass, red-top, wheat, rye, etc. The attacks so far studied, are confined to the culms and sheaths upon the lower part of the stems showing small dark masses of the anthracnose fungus as spots upon them. This shows that the timothy is liable to carry over the disease between the wheat crops.

Bacterial Blight of Head. See blue-grass.

Rust (*Puccinia poculiformis* (Jacq.) W) Some seasons this is very prevalent upon timothy resulting in much spotting and premature drying up of the foliage. This was true to a notable degree in Ohio in 1908.

Smut (*Tilletia striiformis* (Westd.) Wint.) attacks the blades of timothy and produces interesting developments in them. As a rule the amount of smut is not serious. (See smut of blue-grass).

TOBACCO

Bacterial Blight. The same bacterium that attacks potato, egg-plant, etc., at times attacks tobacco plants, especially in the early development. (See wilt).

Fig. 93. Tobacco plants showing bed-rot, Rhizoctonia.

Bed-Rot. Tobacco plants are often destroyed by damping-off fungi; at times even the root-rot fungus may be present in the beds. Owing to the need to use beds several years in succession for plant growing the same fungus which gives us trouble in greenhouses is very liable to give us trouble here. In the old world some of the common damping-off fungi are reported. With us our particular bed-rot troubles are due to Rhizoctonia. For checking this disease it seems desirable to treat the tobacco beds in late fall with formalin drench at the rate of 2 1-2 to 3 pounds of formalin to 50 gallons of water; this to be applied to beds at the rate of one gallon per square foot after spading up thoroughly and incorporating all fresh manure before the treatment is applied. The beds should also be fairly moist. After this treatment no stable manure should be applied, although mineral fertilizers can be used. If the treatments are delayed till spring it will be impossible to sow sooner than two weeks following this drench. (See Circular 59, 1906).

Broom-Rape. In certain infested districts in Brown county the common broom-rape (*Orobanche Ludoviciana* Nutt.) attacks the roots of tobacco, while in Kentucky the hemp broom-rape (*O. ramosa*) also occurs even to a greater extent than in Ohio. Nothing can be done to prevent these attacks of this parasite which produces its own flowers and seeds after once established. If losses are large it would be wise to rotate crops on infested land to get rid of the broom-rape.

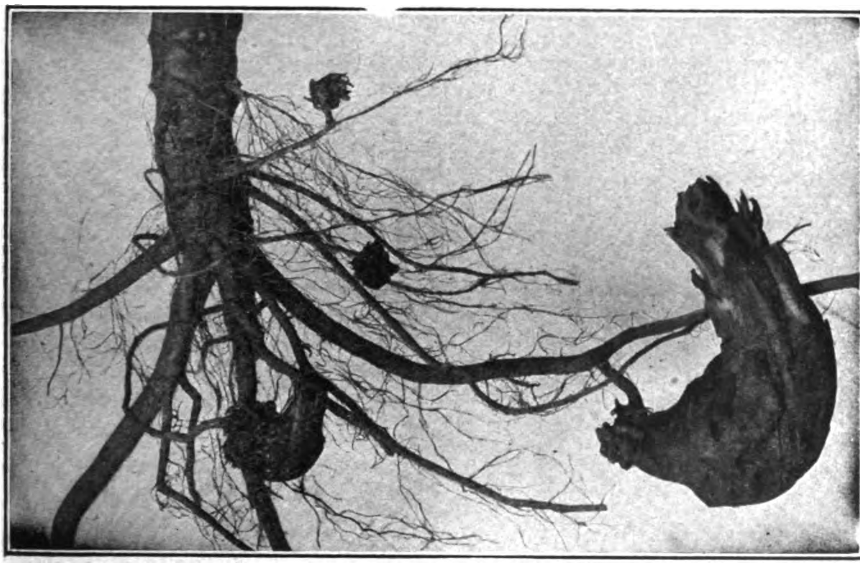

Fig. 94. Roots of white burley tobacco plant attacked by broom-rape. Each of these masses attached to the root shows beginning of the plant which will grow up in larger dense form, and produce an abundance of blossoms and seeds but no leaves. Each one of these must have started from a buried seed of the broom-rape, *Orobanche Ludoviciana* Nutt.

Curing House Troubles. At times tobacco growers have in very moist weather troubles from rotting in the curing house. These are called shed-burn, pole-burn, etc., and are difficult to control under unfavorable weather conditions. Thorough ventilation of the houses is certainly necessary where these are feared.

Downy and Powdery Mildew (*Peronospora sordida* B. & B.) and (*Erysiphe communis* Wallr.) both occur in the old world, but up to this time have not been listed in America.

Leaf-Spot (*Cercospora nicotianae* E. & E.) (*Phyllosticta nicotiana* E. & E.) occurs in some tobacco states, but is very rare with us.

Mosaic Disease also among the enzymatic diseases, is not very common upon tobacco, except in seasons when the normal development of the plants is interfered with by excessive rains and water logged soils. In Connecticut the disease is known as "calico," diseased plants showing a mottled appearance due to the alternating areas of dark green and yellowish green in them; they are

veritable mosiacs. As shown a few years since by Beijerinck, Wood and others, these diseases and others of their class show a yellowing of foliage due to oxidizing enzymes in the leaves. Further as shown in experiments made in 1904, (see Bulletin 156) at Germantown, this disease is communicated from one plant to another by touching. The experiment included touching a succession of plants after touching a diseased plant; these touchings were sometimes repeated. During the period of one month there was an increase of 67 percent in those touched following contact with diseased plants. This shows the advantage of handling mosaic plants at separate times from healthy ones.

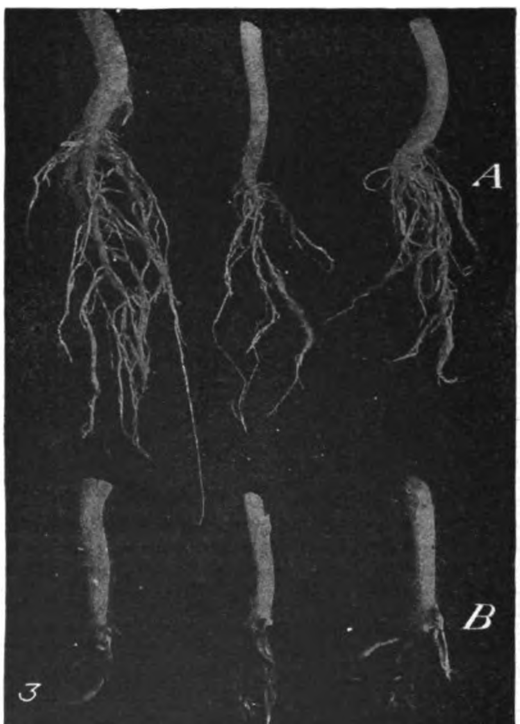

Fig. 95. Roots of seedling tobacco plants from soil inoculated with *Thielavia basicola:* A. Soil sterilized with formalin (1 to 200) and B. untreated. After Gilbert Bulletin 158, Bur. Plant Ind., U. S. D. A.

Root-Rot. Root-rot (*Thielavia basicola* Zopf.) on tobacco was first discovered by the writer upon plants received from Clermont county in 1899; since this time it has been more or less serious during wet seasons. In the vicinity of

Fig. 96. The fungus of tobacco root-rot (*Thielavia basicola* Zopf.). Camera lucida drawing of the fungus as it occurs upon ginseng, tobacco and begonia. *a* and *b*, conidial forms; *c*, ascospores. All magnified 565 diameters. From a drawing by J. M. VanHook.

Hartford, Conn., notably at Litchfield, this disease has been troublesome on certain soils; the same fungus has been found upon catalpa seedlings in Ohio. It is better known as attacking the roots of violets. In all cases there is a blackening and rotting of the roots of seedling plants where they are attacked. Thorough steaming of the bed soil should be practiced where this trouble comes in, to avoid transplanting it to the field. In the field as has recently been pointed out by Gilbert and Briggs, the check on growth of tobacco is much greater in wet seasons than in dry ones. Apparently attention must be given to the drainage of the land which becomes infected if this is to be continued in tobacco.

Wilt (*Bacterium solanacearum* Erw. Smith) has occurred frequently in North Carolina and has more recently been sent to the writer from shade plantations in Florida where considerable acreage was lost in 1908, due to infection through the soil. This bacterial disease has recently been investigated by Stevens and others, but it is not believed any methods of treatment will evade the necessity for rotation. (See Bulletin 156 also potato wilt.)

White Speck has been studied in North Carolina and attributed toa specific fungus (*Macrosporum Tobacinum* E. & E.) Another fungus of the same genus has been accredited in the same state as the cause of brown-rot, but these have not been studied in Ohio.

TOMATO

Anthracnose (*Colletotrichum phomoides* (Sacc.) Chest.) occurs occasionally upon tomato fruits, causing small depressed spots in them. The same fungus may at times attack other parts of the plant. This disease seems to be checked by the use of Bordeaux mixture. (See also Collar disease).

Bacterial Blight of the tomato, egg-plant and potato has already been mentioned. It was destructive at Mt. Carmel, near Cincinnati, in 1896 (B. 73). It has since been locally destructive. It causes sudden blighting and decaying of the stems and branches attacked. Spraying has as yet proved useless for the blight. Preventive measures recommended, include fighting insects, early removal of diseased vines, choice of fresh land not previously in potatoes or egg-plants, and tomato seed from healthy sources. To date this disease has been less destructive than the leaf-spot.

Collar Disease *Vermicularia* sp. Recently a peculiar collar disease of fall greenhouse tomatoes has come under study. In this case the symptoms were abnormal leaf development, after the manner of mosaic disease by artificial inoculation. The collar trouble was quite noticeable.

The case under study occurred in houses that appeared to be over-watered. The plants set very little fruit and were not profitable. The root system appeared to be normally developed except the adventitious whorl of roots near the surface. Between these upper roots and the root crown below, the collar of the plant

is surrounded by a development of what appears to be a parasitic fungus, a species of Vermicularia. The black masses of the fungus are also visible extending down upon the root bases which are lighter in color. A similar abundance of Vermicularia has been noted on the dead stems of potato tops which have died from fusarium blight.

This collar disease is just now under study. We believe something can be accomplished by spraying with Bordeaux mixture about the base of the plants. Certainly good will come by withholding excess water. This case of disease was described where fusarium blight and mosaic disease also prevailed. The fern-like leaf development is ascribed to the presence of the mosaic disease. The association of the two diseases may be casual.

Leaf Mold (*Cladosporium* (?) *fulvum* Cooke) is a common trouble in tomato forcing-houses in the fall or near the close of the season. It produces spots in the leaves, while beneath they are covered by the grayish-brown mold fungus. The fungicides heretofore recommended for use in the greenhouse are available for the tomato leaf mold.

Leaf-Spot or Leaf-Blight is an outdoor trouble, as is anthracnose. The leaf-spot fungus (*Septoria Lycopersici* Speg.) appears to be gradually traveling westward from the Atlantic coast, where it first appeared several years ago. During 1898 it was locally disastrous over the whole of Ohio, and again during 1900 and 1909. It may be successfully prevented by about three thorough sprayings with Bordeaux mixture, though some difficulty attaches to the treatment of unstaked tomato plants in the field. (Bulletins 73, 89, 105).

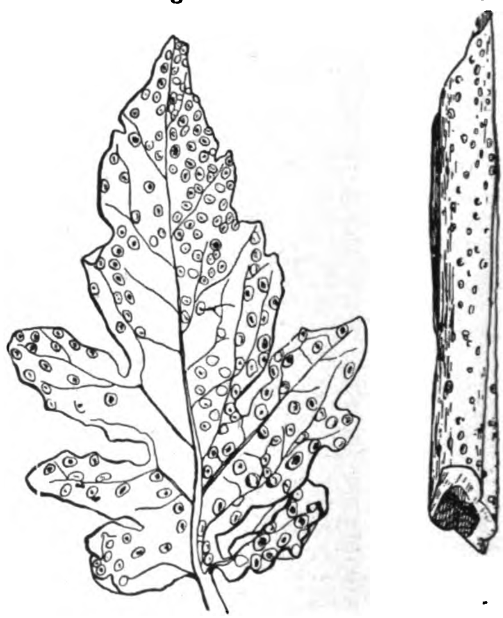

Fig. 97. Tomato leaflet and stem attacked by leaf-spot. This causes dying of the leaves in showery seasons

Mosaic disease attacks the tomato under conditions similar to those giving trouble to cucumbers, tobacco, etc. It is believed we have a mosaic disease analogous to that in tobacco and that the remedy is pointed out by the fact that the disease may be transmitted by touching first diseased and then healthy plants.

The symptoms of the ordinary type of the disease are the alternation of darker green and yellowish-green color in the leaves; this makes the plants conspicuous under ordinary circumstances. In 1909 with cases under glass, where the collar disease appeared to be associated, abnormal leaf forms were observed without very apparent intermixing of yellow areas in the leaves. The actual leaf forms suggested the name of fern-leaf trouble. In these specimens the internodes of the plants, the stems of the compound leaves and the petioles of the leaflets were all elongated; the leaf-blades were narrowed at times to mere borders along the mid-ribs. Gradations were also found between these extreme

forms and the normal leaves. Recent investigations by Westerdijk show the disease to be distinct from the mosaic disease of tobacco though doubtless analogous; the modified leaf forms were obtained by artificial inoculations both by Westerdijk and in the Pathologium of this Station by Manns.

Nematodes may be very injurious to tomatoes grown under glass. They cause, as on cucumber plants attacked, gall-like enlargements on the small roots of the tomato. Previous soil treatment to destroy the nematodes is the remedy in this instance, as in the other. It will usually occur that tomato plants are less susceptible to injury by nematodes than are cucumbers and melons.

Point Rot of green tomatoes, especially in the forcing-house, is often the most serious trouble with which the tomato grower under glass has to contend. It was stated in Bulletin 73 that this trouble was observed to be most destructive in cases of scant water supply in the soil. This observation was again confirmed by the Horticultural Department of the Station during the season of 1899. The trouble was checked by abundant and careful watering, even when it had been very bad, and was again produced by withholding water and allowing the plants to dry out. The cause appears to be largely due to conditions of drouth, and while other causes than the one just stated, notably a certain bacterium does join to produce point rot, none other appears so under control as water conditions. The remedy lies of course, in the avoidance of drouth from which the rot may indirectly result.

Root-Rot or Rosette occurs frequently in greenhouses where tomatoes are grown following crops of lettuce. The fungus produces various effects which are commonly damping off of the younger seedlings or collapse of the older ones; recently a basal constriction of the stem of mature plants is traced to Rhizoctonia. In this case wilting of plants resulted. It seems to be propagated under greenhouse conditions where much organic matter is used and calls for soil disinfection through steaming or formalin drench as described elsewhere under lettuce and under soil diseases. In older plants the symptoms are shortened development of the axis giving effects similar to that in lettuce.

Fig. 98. Stems of young greenhouse tomato plants damped off from attacks of "Rhizoctonia." From a photograph by T. F. Manns.

Sclerotium Blight. This is a wilt disease first reported by Rolfs from Florida but it is now present in Ohio greenhouses. The first symptom is wilting of terminal portion of plant. The dead plants and diseased portions shows in them sclerotia of the fungus which causes the trouble. These are of the size of mustard seed or smaller, at first milk white and finally mahogony red to black. Sometimes these sclerotia grow together in anvil-shaped masses. Burning diseased plants is advised.

Wilt. A wilt (*Fusarium* sp) of tomatoes in addition to that described under bacterial disease has been discovered recently in greenhouses in Ohio as well as other states. It is due to a Fusarium.

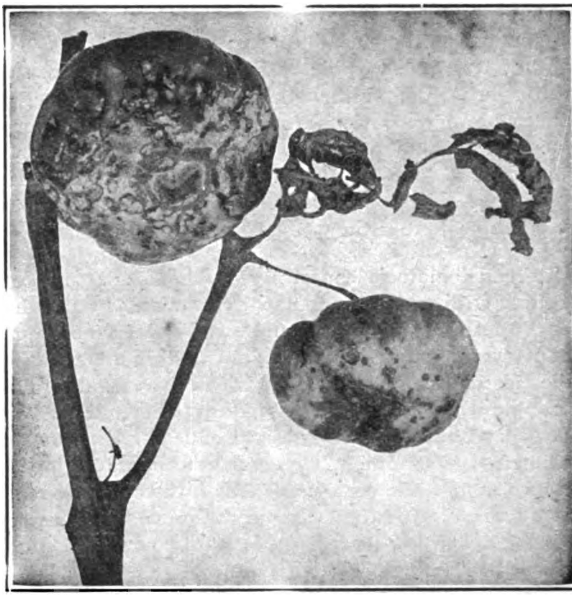

Fig. 99. Tomato fruits with browned and diseased spots in them. This form of disease results from Fusarium Wilt of the plants; also probably from Bacterial Wilt. From a photograph by T. F. Manns.

The symptoms of this wilt are rather characteristic. It may attack plants either vigorous or of slow development. Commonly the first symptom noticed is the yellowing and drying up of the lower leaves. Soon dark areas appear in the stem and also in the fruits. At all stages cross sections show darkening of vessels. The roots become darkened and watery in the region of the vessels. Eventually the top of the plant wilts and the leaves die both above and below, while the fruit has become worthless. We believe this to be a soil infesting disease that should be controlled by thorough soil sterilization.

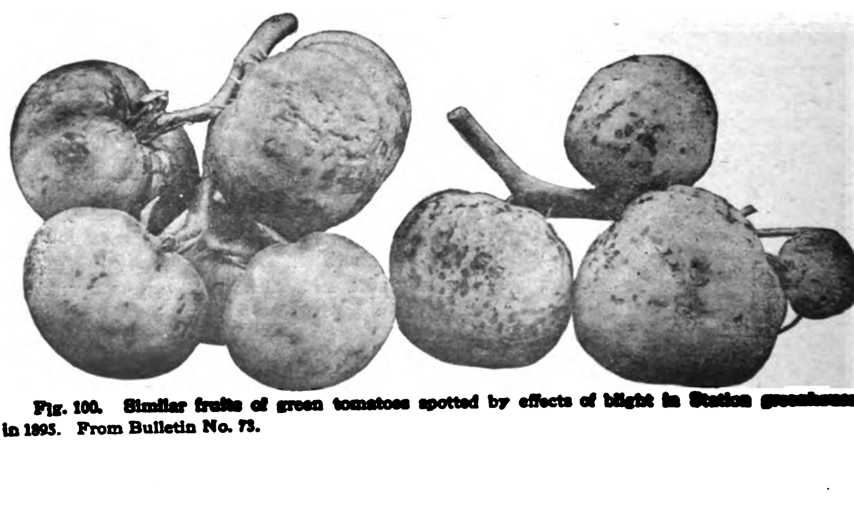

Fig. 100. Similar fruits of green tomatoes spotted by effects of blight in Station greenhouses in 1895. From Bulletin No. 73.

TURNIP

Black-Rot. The same bacterium attacks turnips as cabbage, cauliflower and other mustards; the diseased roots show blackening of the parts with final decay.

Club-Root. This fungus organism (*Plasmodiophora Brassicae* Wor.) infests the roots of many cultivated mustard plants, including the turnip, radish, rutabaga, etc. The treatment is the same as stated under cabbage.

Downy Mildew (*Peronospora parasitica* (Pers.) De By.) sometimes occurs attacking turnip plants.

VERBENA

Mildew. Cultivated verbenas are attacked by the mildew *Erysiphe Cichoracearum* D C) which is so common on the wild vervains. It is to be treated as other powdery mildews, by spraying with fungicides.

VERONICA

Leaf Diseases. Cultivated species of veronica are attacked by several leaf diseases, which have been imperfectly studied. Perhaps the most common of these is due to the typical leaf-spot fungus (*Septoria veronicae* (Rob). There are other parasitic species which attack the genus, including a downy mildew and a rust.

VETCH

Spot. A spot disease (*Protocoronospora nigricans* Atk. and Edg.) has been described as new from New York.

The Wilt of Vetch similar to that of soy beans, cow peas and cotton has also been described.

VINCA

Leaf-Spot. The large flowered vinca is occasionally disfigured by a leaf-spot (*Sphaeropsis vincae* Sacc.) which may also develop as a stem disease. It has not been studied carefully with us.

VIOLET

Leaf-Spot and Leaf Blight (*Phyllosticta Violae* Desm. and *Cercospora Violae* Sacc.) are sometimes prevalent, and with downy mildew of violet should yield to spraying with fungicides.

Nematodes of violets are, on the other hand, not amenable to spray treatment. The parasite in the case is the same as named under cucumber nematodes, likewise its effects. Soil treatment will also be effective in prevention here.

Root-Rot. Root-rot (*Thielavia basicola* Zopf.) has not been reported as troublesome by greenhousemen in Ohio, but it is scarcely possible it can be entirely lacking when the disease occurs upon tobacco and catalpa in fields. The blackening and rotting of the roots, due to the fungus, will impair the development of the plants and the flower growth seriously. It does not seem possible that anything short of sterilizing the soil and starting new plants will check the root-rot where once established.

VIRGINIA CREEPER

Leaf-Spot. The leaves of virginia creeper are frequently curiously spotted by a leaf-spot fungus (*Phyllosticta labruscae* Thüm.) which gives dying spots with colored border. This leaf-spot is also very common upon the Japan creeper and is identical, according to recent reports, with the leaf-spot of the grape; indeed we have a large number of the well known diseases of the grape attacking the Virginia creeper. These include anthracnose, which may be distinct, the black-rot fungus, of which this Phyllosticta may be a stage and possibly others. This would be especially true in the vicinity of cultivated grape vines.

WALNUT

Anthracnose or Leaf-Blight. The leaves of walnut, as well as the leaves on butternut, are attacked by an anthracnose fungus (*Marsonia juglandis* Sacc.) which in common with other anthracnoses, is capable of serious injury to the leaves of these trees. It is believed that this fungus will be held in check by sprays.

Leaf-Spot. The walnut is also attacked by other leaf fungi producing leaf spots, but these have not been investigated by us in Ohio.

Mildew. The same powdery mildew which attacks a variety of trees (*Mycrosphaera alni* DC.) also attacks the leaves of walnut, growing over and forming a mildew covering.

WATERMELON

With the possible exception of the wilt disease and the leaf-spots, the diseases of the watermelon are the same as those which attack cucumbers and musk-melons. They include anthracnose, downy mildew and leaf blight. The leaf-spot of the watermelon is referred to a distinct fungus (*Cercospora citrullina* Cke.) though its ravages are, possibly, not general. (See Bulletins 73, 89, 105). In the treatment of watermelon vines it is advisable to use the more dilute Bordeaux mixture, Bordeaux II, of the calendar.

WHEAT

Anthracnose (*Colletotrichum cereale* Manns). In 1907 centrifuge examinations were made by the Assistant Botanist showing the presence of anthracnose spores in the washings of shriveled wheat samples. The disease was discovered in the fields generally over Ohio in 1908 and has recently been described in Bulletin 203. This anthracnose is certainly the cause of shriveling in wheat. It appears to be the obscure trouble sought for some years by the writer. In common with other anthracnoses it develops as maturity approaches and on wheat it attacks the lower portions of the stems and sheaths resulting in apparent whitening of the spikes with decided shriveling of the grain. The fungus may be detected by the color changes in the field and by the dark spots appearing on the sheaths and stems where attacked. It is believed that thorough separation of shriveled grain by recleaning seed wheat and treatment of seed wheat with formaldehyde drench will be favorable to keeping down the amount of anthracnose. It is admitted that the presence of the fungus upon grasses and

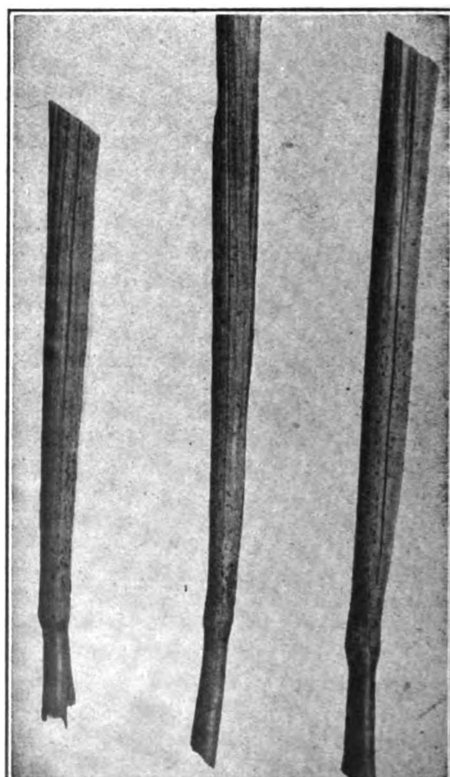

Fig. 101. Culms of wheat with both stems and sheaths attacked by anthracnose. The dark spots are caused by the fungus. From Bulletin 203.

upon other cereals increases the danger of its being carried over in rotation. (See rye, oats, timothy, also Bulletin 203.)

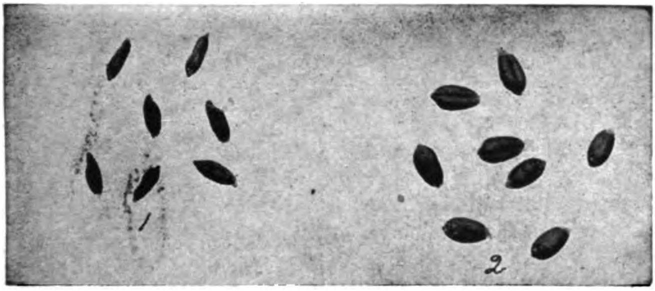

Fig. 102. This shows on the left, wheat shriveled by anthracnose attacks of the plants; on the right normal healthy kernels of wheat of the same variety. From Bulletin 203.

Blade-Spot or Leaf-Spotting has occurred upon wheat in considerable extent in Station plots during the last year or two. Small areas were killed by the fungus and this leads to somewhat premature dying of the leaves This leaf disease calls for further investigations.

Grain Diseases. It must be remembered that anthracnose and scab are both in a sense grain troubles. They cause shriveling and loss of quality in the grain. In addition a fungus (*Alteraria* sp.) causing dark spots in wheat kernels has been found by this department. Scab must also be included here since the parasite attacks the wheat kernels.

Powdery Mildew. This whitish fungus (*Erysiphe graminis* DC.) also appears upon leaves of wheat plants. Usually it is of small importance in Ohio but of much interest.

It attacks wheat both in pot cultures under glass and in outdoor growth. In both cultures the conidial development of the fungus is very troublesome invading the older leaves and causing premature death. In the field the consequences are usually not studied, but the perithecia of the fungus are often found upon straw blades and other parts that have been invaded. It is clear that the fungus cannot be beneficial to the development of the grain in attacked plants.

Scab. The scab disease (*Fusarium roseum* Lk) has been again investigated and the results published in Bulletin No. 203. It has been found that the same scab fungus attacks also rye, emmer, oats and spelt, producing the various effects upon these grains. On all attacked heads in wheat the portion diseased shows reddish or pink covering with the fungus and the part of the spike above this is killed. Of course, all kernels contained in that part are much shriveled and are commonly invaded by the scab fungus. In addition a recent study showed that many various sized kernels of wheat are infested with this fungus internally, although still capable of starting to grow and making a new plant. Investigations made in

Fig. 103. Wheat spike attacked by scab. The upper portion of the head is shrunken and has been killed by the pink fungus.

culture dishes and greenhouse recently, show that the fungus survives in the old dead seeds as well as in some capable of germination and attacks the seedling wheat plants during the first month of their growth. In the continuous wheat plots of the Station it was found that nearly 6 percent of the plants were killed off in the unfertilized plots during 1907; the fertilized plots show a good deal less and the rotation plots a great deal less (see Bulletin 203). Not only may the fungus survive in its perithecial form upon wheat heads, straw and dead scab grains, but it may survive in grain capable af germination as well as in the soil. See pages 334-335. Recent studies of diseases of clover and alfalfa seem to show that this same fungus is the cause of serious clover and alfalfa sickness. It would thus appear to be carried over through rotations of clover, etc. The best method of handling appears to be recleaning seed wheat and getting out all shriveled kernels which are often scab-infested as well as all under sized kernels thus evading a large share of the infection in seed wheat.

Seedling Blight. The seedlings of wheat are killed off by the attacks of the scab fungus which is transmitted in the seed as well as in the soil devoted to continuous wheat culture. (See scab above, also Bulletin 203.)

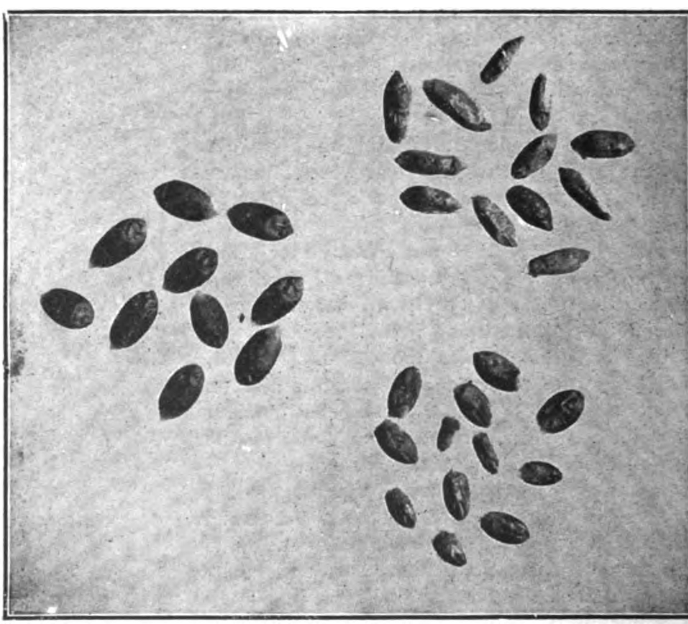

Fig. 104. On left, healthy normal kernels of wheat; on the right, above kernels injured by scab which will not germinate—below kernels injured by weavil. From Bulletin 203.

Loose Smut. This is a smut fungus (*Ustilago Tritici* Jensen) which converts grain and glumes into a sooty mass of spores. These heads of loose smut are most obvious at the blossoming of the wheat. The disease is worse on certain varieties of wheat. It may be prevented by the modified hot water treatment as per calendar.

Rust. While essentially the same to the ordinary observer, the wheat rust is produced by two rust fungi (*Puccinia graminis* Pers. & *P. rubigo-vera* D C). Only the last named passes the winter in the wheat plant. Both have the light red and the black (dark) stages and are very damaging under conditions which favor the rust. In Europe, Australia, and California wheat growers hope to select rust proof varieties of wheat. Recently in England quite an impetus has been given to wheat breeding by the work of Biffen upon resistant varieties of wheat. This resistance applies in the English studies not only to rust, but to some other features. The matter of resistance is the hope of rust prevention. (See Bulletin 97.)

Fig. 105. Heavy spike of bearded wheat destroyed by loose smut. These smut spores are scattered and find entrance into the forming kernels of wheat when the blooms open for pollination.

Stinking Smut of wheat is caused by a still more destructive smut fungus, (*Tilletia foetens* B & C) which converts the kernels of wheat into dirty, stinking masses of spores. These, if abundant, ruin the flour and render the wheat valueless for human food. At times 40 percent of the wheat is thus destroyed and the losses from it are often very large. Recent investigations have established that this smut is caused by the smut spores sown with the seed grain. If the smutty seed wheat is treated with a fungicide, such as bluestone, hot water, formalin, etc., which will destroy these spores without injury to the grain and the treated seed is then prevented from subsequent infection, dried and sown, a clean crop may be grown from smutted seed. For details of treatment see calendar and Bulletin 97, which treats of the diseases of wheat.

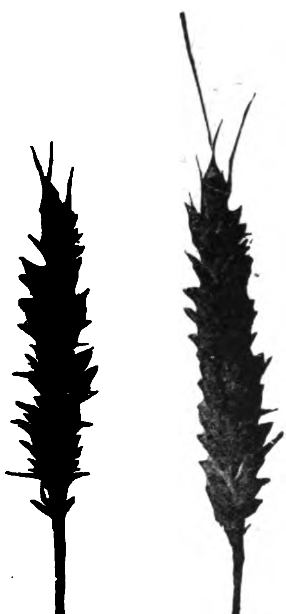

Fig. 106. Diseased and sound spike of Poole wheat. In the one at the left the kernels have been destroyed by Stinking smut and spikelets are spread abruptly.

WHITE PINE

See Pine.

ADDENDUM

Corn, Root-Rot, (*Fusarium* sp.). Recently the Department has made preliminary studies of a root-rot of corn attributed to a species of Fusarium of similar behavior to the scab of wheat, potato fusarium and cabbage wilt, in that the parasite appears to survive in the affected soil, as well as elsewhere. From Fayette county comes the report of diseased corn roots in patches where the stalks blow over easily, and rarely form mature ears. Roots of such plants are partly killed and thus weakened. At present we can only advise rotation of crops. More knowledge is needed with all this type of soil infesting diseases.

Raspberry, Cane Blight (New York). In reference to cane blight conditions, page 437, this specific disease described by Stewart (Bul. 226, N. Y. Agric. Expt. Sta., 1902) was not mentioned. Stewart identified the disease on specimens sent to him from Ohio in 1902. Recently other specimens have been received from Cuyahoga and Wood counties. The earlier reference to cane blight forms indicates how serious the raspberry condition is in Ohio. The parasite causing the disease is *Coniothyrium Fuckelii* Sacc. The fungus attacks the plants killing and discoloring the bark and wood, thereby causing wilting of bearing canes, and the ultimate death of the parts that have been attacked. The foliage on affected canes wilts suddenly and becomes dry. The whole cane may be involved, or only a part of it. At times a single branch is killed, while the remaining cane continues apparently normal. It is feared that this disease is very common in our unprofitable raspberry plantations in Ohio. The disease is doubtless disseminated in plants from diseased plantations, and by the ordinary agencies of wind, rain, etc. Naturally the dissemination by these last two agencies is local. Preventive measures will include healthy plants, planting on new uninfected land and a prompt cutting out and burning of old canes after fruit is gathered. Stewart's work indicates inconclusive results from spraying.

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METHODS FOR THE QUANTITATIVE ESTIMATION OF INORGANIC PHOSPHORUS IN VEGETABLE AND ANIMAL SUBSTANCES

OHIO
Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., APRIL, 1910

BULLETIN 215

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CONTENTS

PREFACE.

That portion of this bulletin which has to do with plant substances marks the first step in a program of investigation of the phosphorus compounds of the food of animals.

This study is necessary as a preliminary to the practical application of the results of our animal metabolism experiments with pure phosphorus compounds.

The greatest difficulty in the way of a quantitative estimation of the groups of phosphorus compounds in vegetable substances has been the accurate separation of inorganic phosphates from the salts of phytic acid.

The solution of this problem opens up an important field to a new and promising line of attack, and points the way with considerable certainty to the estimation of phytin and nuclein phosphorus.

The solution of the problem of estimation of inorganic phosphorus in a wide range of animal tissues makes judgment possible as to the availability of the phosphorus of the food for the nutrition of the functional substance of these parts.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 215. APRIL, 1910

METHODS FOR THE QUANTITATIVE ESTIMATION OF INORGANIC PHOSPHORUS IN VEGETABLE AND ANIMAL SUBSTANCES.

BY E. B. FORBES, A. LEHMANN, R. C. COLLISON AND A. C. WHITTIER.

INTRODUCTION.

In studying the nutritive value of vegetable foods, either in their usual state, or as modified by the chemical constitution of soils or fertilizers, it is important that we distinguish between organic and inorganic phosphorus, and in considering the specific effects of nutrients on the development of animals and the composition of their organs and tissues, it is a matter of great interest and importance that we know whether or not variations in their phosphorus content involve the simple inorganic salts in solution in their liquids, or the complex organic phosphorus compounds of the living structures.

This distinction is of significance in animal nutrition especially, because of the limited usefulness as nutrients of mineral elements in an inorganic condition.

We have no reason to expect that variations in the food will produce especially marked variations in the inorganic phosphorus content of animal tissues. In order, therefore, to get the results desired, it is necessary that the method used for the estimation of inorganic phosphorus be as nearly as possible chemically and mechanically perfect.

On these accounts, and as a part of the general program of study of the nutritive value of compounds of phosphorus, which is in progress in this department, we have undertaken a solution of the problem of quantitative estimation of inorganic phosphorus in plant and animal substances generally.

A number of methods for these determinations have been published but have been found to be either inaccurate or cumbersome, and therefore we have given the subject some attention.

Conclusions have been reached which give us convenient and approximately accurate methods for the estimation of inorganic phosphorus in a wide range of plant and animal substances.

As a problem in quantitative chemical analysis the estimation of inorganic phosphorus in vegetable substances is rendered particularly difficult by the facts that in each substance under observation we have a different mixture of phosphates, variously related, both chemically and physically, to different groups of organic compounds.

The problem of complete extraction may be influenced by the mechanical relation of the phosphates to insoluble and impenetrable structures, and the possibility of hydrolysis of organic phosphorus compounds by the extractive reagents introduces into the problem an element of uncertainty for the removal of which our present knowledge of the relations of phosphorus to organic compounds in plants does not begin to suffice.

Further, combinations of inorganic phosphorus with organic compounds, such as may occur without the agency of a vital process in a living organism, introduce an element of embarrassment into the discussion, as also does the fact that there is no clear-cut and essential distinction between organic and inorganic compounds generally, but these several objections to the general idea of such a separation as we contemplate do not have weight sufficient to prevent the solution of the problem on a useful working basis.

ESTIMATION OF INORGANIC PHOSPHORUS IN VEGETABLE SUBSTANCES.

Of the various methods which have come to the attention of the authors, that used by Hart and Andrews* appeared to give the most specific starting-point for further work. The essential points of this method are as follows:

1. Extract 5 grams of sample by shaking for 15 minutes in 125 c. c. of .2 percent hydrochloric acid.
2. Filter, and wash with water until filtrate measures 500 c. c.
3. Neutralize a 200 c. c. portion of this filtrate with ammonia. Precipitate at 65° with 10 grams of ammonium nitrate, 25 c. c. of neutral ammonium molybdate solution and 2 c. c. of nitric acid, specific gravity 1.20. Keep at this temperature for 15 minutes; allow to cool gradually, and filter after one hour.
4. Treat this precipitate as is usual in a phosphorus estimation, dissolving in ammonia, precipitating with magnesia mixture, burning to the pyrophosphate, and then redissolving and reprecipitating to free from impurities.

*Bul. 238, New York Agr. Exp. Sta., p. 188.

Hart and Andrews found that the official molybdate solution decomposed nucleinic acid.[1]

In order to reduce this decomposition to a minimum they used neutral ammonium molybdate solution with just sufficient nitric acid to precipitate the phosphoric acid present. This quantity they state to be 2 c. c. of 1.20 nitric acid.[2]

The second precipitation as magnesium ammonium phosphate was advised by them to remove from the pyrophosphate possible contamination from magnesium oxide resulting from proteid-magnesium compounds precipitated along with the magnesium ammonium phosphate by the magnesia mixture.[3]

In making use of this method we found it not entirely satisfactory, and on the following accounts:

1. The time allowed for extraction appears to be insufficient.

2. The precipitation with neutral molybdate solution and the minimum amount of acid, is rendered difficult, as a routine method, by the fact that 2 c. c. of 1.20 nitric acid are in many cases not nearly sufficient to cause precipitation of the inorganic phosphorus.

3. The bulky, flocculent precipitate which is often formed may completely mask the formation of the yellow precipitate of inorganic phosphorus, rendering it impossible to judge of the completeness of the precipitation.

4. The precipitate is, with many products, very difficult to filter.

5. This method involves the precipitation of inorganic phosphorus in the presence of phytin. A quantitative precipitation of inorganic phosphorus alone, from a solution containing phytin, appears to be impossible.

6. Nucleinic acid may be hydrolized by the nitric acid used in this precipitation, the result being the formation of inorganic from organic phosphorus.

7. Nucleinic acid, like phytin, appears to hinder the formation of the yellow precipitate.

8. A possible source of error lies in the carrying down of phosphorus-containing proteids with the yellow precipitate, the solution of these proteids in ammonia, their precipitation with magnesia mixture, and in this way their contribution to the amount of the pyrophosphate.

In an attempt to remedy the imperfections of this method we made the following observations:

[1]Bul. 238, New York Agr. Exp. Sta., p. 188.
[2]Bul. 238, New York Agr. Exp. Sta., p. 189.
[3]Bul. 238, New York Agr. Exp. Sta., p. 191.

The time of extraction in .2 percent hydrochloric acid may be safely lengthened, at least for most substances, to three hours.*

The decomposition of nucleinic acid by the nitric acid used in the molybdate precipitation, is obviated by substituting for this first process, a precipitation with magnesia mixture, since free nucleinic acids and some at least of their salts are soluble in ammonium hydrate.

Besides getting rid of the nucleinic acids, this precipitation largely removes the mechanical difficulty of handling the bulky, flocculent, molybdate precipitate, and obviates the necessity for the delicate determination for each substance studied, of the point of compromise between completeness of precipitation of inorganic phosphates and decomposition of organic phosphorus compounds by nitric acid.

The precipitate with magnesia mixture is very much less bulky, and is more easily filterable, and in this case there is no doubt as to the completeness of the process.

The interference of phytin with the estimation of inorganic phosphorus, which may amount to a complete suppression of the yellow precipitate if this compound be present in considerable amount, or which may, through decomposition, add to the inorganic phosphorus if the phytin be present in smaller quantity, is entirely done away with by the separation of phytin and inorganic phosphorus in the precipitate with magnesia mixture, by dissolving the inorganic phosphates out of this precipitate with acid-alcohol. The phytin is practically, if not entirely insoluble in this reagent.

Below are details of work sustaining these conclusions.

The problem of removal of nucleinic acids from the .2 percent hydrochloric acid extract was worked out by experiments with a preparation of nucleinic acid from yeast. The free nucleinic acid and some of its salts, at least the magnesium compound, proved soluble in ammonium hydrate. This fact led to the separation of inorganic from nucleinic acid phosphorus by precipitating with magnesia mixture and filtering out the precipitate.

The preliminary precipitation with magnesia mixture has the double advantage of removing the nucleinic acid and of facilitating subsequent work. After dissolving the magnesia precipitate in hydrochloric acid, the molybdate solution produces a normal yellow precipitate which is free from the bulky flocculent mass which frequently entirely obscures, if indeed it does not prevent, the

*The use of phenol in the extractive reagent would probably prevent the activity of enzymes in substances where they are particularly active, though unless proven necessary the use of phenol is inadvisable.

formation of the yellow precipitate when the hydrochloric acid extract of the substance is treated directly with the molybdate solution.

After working out this point we learned from correspondence with Parke, Davis & Co., of Detroit that this magnesia precipitation was in use by this firm in the estimation of inorganic phosphorus in their preparation of nucleinic acid from yeast.

In order to determine whether or not nucleinic acid was decomposed in ammonia solution during our first magnesia precipitation, we weighed out three 1-gram portions of nucleinic acid which had been prepared from yeast. These were dissolved in ammonia, and allowed to stand over night with magnesia mixture, as in the first step of our method for inorganic phosphorus estimation. Slight precipitates formed, which we combined, dissolved and reprecipitated, first with molybdate solution and then with magnesia mixture, but the combined precipitates were unweighable.

That conditions were correct for precipitation of inorganic phosphorus, was proven by addition of sodium phosphate to another sample of nucleinic acid, which was dissolved and treated like the three above mentioned. The phosphorus came down promptly in the usual way.

U. Suzuki and others* have found that in certain foods and fodders which they examined, including wheat bran and barley, a large portion of the organic phosphorus is present as phytin, and that accompanying this is an enzyme which decomposes phytin into phosphoric acid and inosite.

Attempts were made to prevent possible decomposition by enzymes during the estimation of inorganic phosphorus, by previous heating of the material, both by dry heat and by boiling, but the results were unfavorable to the use of this principle in a routine quantitative method.

After demonstrating that a longer time of extraction than 15 minutes was desirable, we sought to learn whether or not the action of enzymes might be expected to enter largely into the determination of results with the longer extraction.

Inorganic phosphorus was determined in two samples of wheat middlings by two different methods of procedure.

The extractions were made with .2 percent hydrochloric acid, and the extracts allowed to stand over night, two with 6.6 percent of phenol in the extractive reagent, and the other two in the .2 percent hydrochloric acid alone. The extracts were allowed to stand over night in order to give the enzymes a fair chance to demonstrate their presence.

*Bul. No. 4, Vol. 7, College of Agriculture, Tokio.

One sample gave us .006 percent of inorganic phosphorus with phenol present and .010 percent without. The other sample gave .005 percent and .012 percent with and without phenol.

While the amounts of inorganic phosphorus involved were very small the variations in the percent of inorganic phosphorus were considerable, and on the strength of this evidence we began the use of phenol in our provisional method, without having demonstrated that enzymes would make an appreciable difference in the inorganic phosphorus during our three-hour extraction, and without having determined that there was no bacterial growth in our .2 percent hydrochloric acid extract during the twenty-four hours which it stood.

These above results are comparative only, since they were obtained by precipitation in the presence of phytin.

After some preliminary work with the method of Hart and Andrews, certain modifications were compared with the original method. The results are set forth in the following table.

COMPARISON OF MODIFICATIONS OF HART AND ANDREWS'S METHOD

Percent of Inorganic Phosphorus

		Method 1	Method 2	Method 3	Method 4
		Hart's method, 15 minutes extraction; 2 c. c. nitric acid used in precipitation	Hart's method as in Column 1, but with 3 hrs. extraction; 2 c. c. nitric acid used in precipitation	Hart's method as in Column 1, but with 3 hrs. extraction, and 7 c. c. nitric acid used in precipitation	Modified by use of phenol in extractive reagent, and preliminary magnesium precipitation; phosphorus then precipitated by official molybdic solution
1	Gluten flour.......	.035	.053	.053	.044
2	Gluten feed.... ...	.062	.119	.171	.149
3	Cotton seed meal..	.044	.105	.140	.118
4	Distiller's grains..	.039	.055	.082	.067
5	Corn stover........	.028	.061	.086	.078
6	Bermuda grass....	.020	.131	.179	.174
7	Alfalfa hay........	.028	.097	.145	.140
8	Clover hay........	....	.073	.103	.091

With the Hart and Andrews method as in Columns 1, 2, and 3, the preliminary precipitation was with neutral molybdate solution and varying amounts of nitric acid.

It will be observed that the figures in the second column are all higher than the corresponding figures in the first column, showing that 15 minutes extraction is insufficient.

There is, of course, a possibility that the greater amount of inorganic phosphorus found by the three-hour extraction, than by the fifteen-minute extraction, is due to hydrolytic decomposition of organic phosphorus compounds by the .2 percent hydrochloric acid during extraction, rather than to greater thoroughness of extraction.

In order to test this point we determined the inorganic phosphorus in phytin and in nucleinic acid, in one set of samples precipitating immediately after solution, in another set after 3 hours' standing, and in a third after 24 hours' standing in the .2 percent hydrochloric acid. We were unable to demonstrate decomposition in this reagent in either 3 or 24 hours' extraction.

The figures in the third column are, with one exception, higher than the figures in the second, which may be due either to the 2 c. c. of nitric acid used in Method 2 being insufficient to cause complete precipitation, or to the 7 c. c. of acid used in Method 3 being excessive, and augmenting the amount of inorganic phosphorus by decomposition of organic forms, or both decomposition and incomplete precipitation may have affected results.

After precipitation of inorganic phosphorus as with Method 2 with 2 c. c. of nitric acid, 5 c. c. of nitric acid were added to the filtrates to test the thoroughness of the precipitation. The characteristic yellow precipitate promptly appeared in all cases, except with gluten flour.

The figures with Method 4 are, with one exception, higher than the corresponding figures with Method 2, showing that the 2 c. c. of nitric acid used with Method 2 were insufficient. These figures are with one exception, lower than the corresponding figures with Method 3, showing that either the use of phenol in the extractive reagent, or the elimination by the magnesia precipitation of the possibility of decomposition of nucleinic acid by nitric acid, or both, tended to obviate probable inaccuracies in this method of work.

Subsequent investigation, however, showed that Method 4 was unreliable, because of the presence of phytin in the solution from which the inorganic phosphorus was precipitated; so the determinations have a comparative but not an absolute value.

In order to study the bearing of fineness of grinding of the sample on this method of work, a coarsely ground sample of bluegrass was divided into two equal parts and one of these was reground. Both samples were then passed through standard seives with the following results:

PERCENT OF MATERIALS RETAINED BY SEIVES

	2 mm.	1 mm.	.5 mm.	Pan
Coarsely ground................	0	44	33	23
Finely ground................	0	0	7	93

Method 4 gave .106 percent of inorganic phosphorus in the finely ground sample and .109 percent in the coarsely ground sample, indicating that extreme fineness of division of such fodders as

blue-grass is probably not essential, and that our failure to extract all of the inorganic phosphorus in 15 minutes was in all probability not due to insufficient fineness of division of the material.

The method of extraction and precipitation used throughout the greater part of this study is as follows:

Place 25 c. c. of 90 percent phenol in a flask graduated to deliver 500 c. c.; add a small portion of .2 percent hydrochloric acid, and shake the flask until the phenol is dissolved. Then fill to the mark with .2 percent hydrochloric acid, and pour the contents upon 10 grams of the sample in a 600 c. c. Florence flask. Close the flask with a rubber stopper and shake at intervals of 5 minutes for three hours.

At the end of this period filter the extract through a dry paper. To a 350 c. c. portion of the filtrate add 10 c. c. of magnesia mixture and 50 c. c. of strong ammonia, and allow to stand over night.

Inorganic phosphorus is precipitated as magnesium ammonium phosphate, along with phytin if present, while nucleins, being soluble in ammonia, remain in solution. Next morning filter, and wash the precipitate free from phenol with dilute ammonia.

In the case of materials containing phytin, such as wheat bran and middlings, the precipitate consists almost wholly of phytin and magnesium ammonium phosphate. It is dark gray in color, and usually completely soluble in dilute acids. In the case of materials containing no phytin, it consists of impure magnesium ammonium phosphate, usually contaminated with variously colored unknown compounds.

Determination of inorganic phosphorus in this precipitate by dissolving in dilute acid, and precipitation with molybdate solution, did not give true results in the presence of phytin.

Experiments were now made on the action of phytin on the precipitation of inorganic phosphorus. In this work a commercial preparation of phytin was used. This material was a calcium-magnesium salt prepared by the Society of Chemical Industry, in Basle, Switzerland. It contained 19.9 percent of phosphorus. The sample was probably contaminated by a small quantity of inorganic phosphorus, since a separation from the latter is very difficult.

Definite quantities of this phytin were dissolved in 0.2 percent hydrochloric acid; a definite quantity of inorganic phosphorus in the form of di-sodium phosphate was added, and the solution precipitated with official molybdate solution in the usual way.

The following series of figures gives the results of the first trial:

The phytin in each case was dissolved in 100 c. c. of 0.2 percent hydrochloric acid, to which was added di-sodium phosphate, equivalent to 0.0420 gram of magnesium pyrophosphate. Ammonium nitrate and 40 c. c. of official molybdate solution were used in the precipitation of the inorganic phosphorus. The number of grams of phytin in each case represents approximately the percent of phytin in the solution.

SUPPRESSION OF YELLOW PRECIPITATE BY PRESENCE OF PHYTIN

Grams of phytin	Grams of pyrophosphate equivalent to inorganic phosphorus added	Grams of pyrophosphate recovered
1.0	.0420	.0000
0.5	"	.0260
0.4	"	.0329
0.3	"	.0371
0.2	"	.0423
0.1	"	.0447
0.05	"	.0438
0.03	"	.0433
0.01	"	.0422
0.00	"	.0420

The striking fact about this series is that a one-percent solution of phytin completely suppressed the precipitation of the inorganic phosphorus present, there being no yellow precipitate after an hour's digestion at 65° C. This suppression of the yellow precipitate seemed to diminish with decrease in the phytin content of the solution, as shown by the increase in the weights of pyrophosphate as the corresponding amounts of phytin were decreased from 1 gram to .2 of a gram. With continued decrease in the phytin present, however, the results increased to quantities in excess of the blank. This may have been due to a decreased suppression of the precipitate by the lower percentages of phytin, the phosphorus in excess of the blank being contributed by the inorganic phosphorus present as an impurity in the phytin; or with decrease in the amount of phytin present, there may have been an increased splitting off of inorganic phosphorus from phytin.

The result on a .2 percent solution of phytin may have been due to a combination of two compensating errors, one the partial hydrolysis of phytin, and the other the partial suppression of precipitation by the presence of phytin, the combination of these factors resulting in a check with the blank.

Later results indicate that the high results with the low percents of phytin were partly due to the formation of inorganic phosphorus by the decomposition of phytin.

The results would naturally be higher than the blank because of the presence of appreciable quantities of inorganic phosphorus in the phytin sample, but this would not account for the low results obtained when considerable phytin is present, nor for the high results later obtained on low-phytin solutions. Duplicate series of determinations were made, all of which gave similar indications.

When using neutral molybdate, although decomposition was not so marked, as indicated by high results on low-phytin solutions, it was necessary in many cases to add more than the 2 c. c. of nitric acid, as specified by Hart and Andrews, in order to effect a separation of the yellow precipitate, while in 0.5 percent and 1.0 percent solutions of phytin, the yellow precipitate was completely suppressed as before.

It was also observed at this time that when the di-sodium phosphate solution was added to the 0.2 percent hydrochloric acid solution of phytin, a cloudiness was at first produced, which disappeared on stirring. In a one-percent solution of phytin it was found possible actually to precipitate the phytin with a strong solution of di-sodium phosphate, indicating either a partial salting out of the phytin, or a combination of inorganic phosphate with the phytin, due to a possible unsaturated condition of the latter.

Considering the results obtained thus far, it was obvious that a separation of phytin from inorganic phosphorus was necessary, if exact results were to be secured.

A quantitative separation of inorganic phosphorus from such a substance as phytin, is a task attended by considerable difficulty, because of the similarities in solubility and the difficulty of preventing hydrolysis of the phytin.

No organic liquid was found in which phytin is appreciably soluble. The only solvent seemed to be dilute acids, in which, of course, inorganic phosphates are also soluble. Phytin is precipitated from such solutions by alkalis and strong alcohol. Inorganic phosphates precipitate under the same conditions, when bases such as calcium and magnesium are present, as in the case of acid extracts of feeding materials.

Owing to the very limited number of solvents for phytin, methods of precipitation in acid solution were investigated.

It was found that aluminium salts cause a precipitation of phytin in a 0.2 percent hydrochloric acid solution of the latter. By adding ammonium nitrate and digesting at 60° C. we were able to prceipitate the phytin from even a .01 percent solution of the same.

A number of series of determinations were made, using potash alum as the precipitant. The phytin was in each case dissolved in 100 c. c. of 0.2 percent hydrochloric acid in a 250 c. c. flask. Inorganic phosphorus was added as usual, and also 30 grams of solid ammonium nitrate. The flask was filled nearly to the mark with 0.2 percent acid, and then the phytin precipitated with a small excess of a saturated solution of alum. The flask was then filled to the mark, shaken, and the contents digested at 60° C. for one hour. The contents were then filtered through dry papers, and a measured portion was taken for determination of inorganic phosphorus. Under these conditions phytin was precipitated even in 0.01 percent solutions, but came down as an exceedingly soft, bulky and finely divided precipitate, which could not be held satisfactorily by any kind of filter. A series made by this method gave the following results:

SEPARATION OF INORGANIC PHOSPHORUS AND PHYTIN BY PRECIPITATIÓN WITH POTASH ALUM

Grams of phytin present	Grams of pyrophosphate equivalent to inorganic phosphorus added	Grams of pyrophosphate recovered
0.5	.0672	.0621
0.4	.0672	.0654
0.3	.0672	.0656
0.2	.0672	.0657
0.1	.0672	.0664
0.05	.0672	.0645
0.04	.0672	.0644
0.03	.0672	.0650
0.02	.0672	.0650
0.01	.0672	.0652

At the same time, samples of the phytin used were treated in a similar way, without the addition of inorganic phosphate. They gave the following results:

Grams of phytin present	Grams of pyrophosphate recovered
0.5	.0117
0.3	.0095
0.1	.0033
0.05	.0009

Now if these latter values are assumed to represent the amount of inorganic phosphorus in the phytin sample, they should be added to the .0672 gram present in inorganic form in order to obtain the true values for inorganic phosphorus; for example, in the case of a 0.5 percent solution of phytin, .0672 gram of pyrophosphate should have been recovered, plus what the phytin itself contained, namely .0117 gram. Therefore, .0672+.0117=.0789 gram magnesium pyrophosphate, which presumably represents the correct value for inorganic phosphorus in the 0.5 percent solution.

When the series is thus worked out it is readily seen that the results are all too low.

Thinking that possibly the low results were due to a dragging down of inorganic phosphorus by the bulky precipitate of phytin, we made several series of determinations in which the precipitate was thoroughly washed with warm 0.2 percent hydrochloric acid, but in all cases the precipitate, being so finely divided, was washed through into the filtrate. It could not be held by filter paper, paper pulp or asbestos.

We next tried precipitating the phytin as the lead salt in 0.2 percent nitric acid solution. The details of the method were similar to those of the alum method, except that no ammonium nitrate was used in the digestion of the precipitated lead salt.

By the use of a 20 percent solution of lead nitrate, complete precipitation of the phytin seemed to be obtained. The precipitate was heavier and more easily filtered than the aluminium salt.

Experiments proved that 0.2 percent nitric acid was the best medium in which to make the precipitation.

This method gave results indicated by the following series:

SEPARATION OF INORGANIC PHOSPHORUS AND PHYTIN BY PRECIPITATION WITH LEAD NITRATE

Grams of phytin present	Grams of pyrophosphate equivalent to inorganic phosphorus added	Grams of pyrophosphate recovered
0.4	.0304	.0256
0.3	.0304	.0295
0.1	.0304	.0305
0.05	.0304	.0311
0.04	.0304	.0304
0.03	.0304	.0327
0.01	.0304	.0312

Four determinations were also made on the phytin sample without addition of inorganic phosphorus as follows:

Grams of phytin present	Grams of pyrophosphate recovered
0.4	.0053
0.3	.0022
0.2	.0011
0.1	.0003

The low results on solutions with high phytin content again indicate either a dragging down of inorganic phosphorus by the heavy precipitate of lead phytate, or actual combination between phytin and inorganic phosphates.

It was also thought possible that the particular form of the commercial phytin used might be accountable for these varying results. To test this, several series of determinations were made with the lead precipitation on extracts of feeding materials.

The method of procedure was as follows:

From 50 to 100 grams of material were extracted for three hours with a large volume of 0.2 perçent hydrochloric acid. The resulting extract was filtered through paper by suction. Measured portions of this extract were placed in beakers, and a definite amount of di-sodium phosphate added, as before. The mixture was then precipitated with magnesia mixture and ammonia, using 10 c. c. of the former to 20 c. c. of the latter. After standing over night, the precipitate was filtered off and washed with dilute ammonia. After draining well, the paper with the precipitate was placed in a flask containing 250 c. c. of 0.8 percent nitric acid, and shaken until the paper and precipitate were thoroughly broken up. This solution was then filtered through a dry filter, and 200 c. c. of the filtrate placed in a 250 c. c. flask. After making neutral with ammonia, enough nitric acid was added to make the 250 c. c. of solution contain 0.2 percent of nitric acid. Lead nitrate solution was now added in slight excess, the flask filled to the mark, and digested for one hour at 60° C. The phytin was then removed by filtration through a dry filter, and after cooling, 200 c. c. of the filtrate was precipitated with official molybdate solution. The yellow precipitate was washed with diluted molybdate solution until free from lead, and phosphorus was then determined in the usual way.

This method gave the following results on wheat bran, and was also tried on alfalfa, which is thought to contain no phytin*.

One hundred grams of bran were extracted with 1500 c. c. of 0.2 percent hydrochloric acid containing 25 c. c. of 90 percent phenol.

To measured portions of this extract was added di-sodium phosphate solution equivalent to a final weight of .0246 gram of magnesium pyrophosphate.

SEPARATION OF INORGANIC PHOSPHORUS AND PHYTIN BY PRECIPITATION WITH LEAD NITRATE IN ACID EXTRACT OF WHEAT BRAN

Volumes of extract	Pyrophosphate equivalent to inorganic phosphorus added	Pyrophosphate recovered	Calculated weight of pyrophosphate
C. C.	Grams	Grams	Grams
100	.0246	.0326	.0338
80	.0246	.0320	.0320
60	.0246	.0288	.0302
50	.0246	.0290	.0284
40	.0246	.0286	.0273
25	.0246	.0275	.0269
10	.0246	.0258	.0255
5	.0246	.0253	.0251
100	.0000	.0091	......

*Hart and Tottingham: Journal of Biological Chemistry, Sept. 1909.

The fourth column refers to results which should have been obtained if .0091 gram of pyrophosphate is considered to represent the amount of inorganic phosphorus in the 100 c. c. of extract taken; and to this is added the blank, .0246 gram pyrophosphate, which had been added as di-sodium phosphate. For quantities of extract less than 100 c. c. proportional parts of the value .0091 were taken.

A similar series of determinations was made on alfalfa hay. Forty grams of alfalfa hay were extracted with 1000 c. c. of 0.2 percent hydrochloric acid containing 50 c. c. of 90 percent phenol. The inorganic phosphate added was again equivalent to .0246 gram pyrophosphate.

RECOVERY OF INORGANIC PHOSPHORUS ADDED TO ACID EXTRACT OF ALFALFA

Volumes of extract C. C.	Pyrophosphate equivalent to inorganic phosphorus added Grams	Pyrophosphate recovered Grams	Calculated weight of pyrophosphate Grams
100	.0246	.0343	.0338
80	.0246	.0330	.0320
60	.0246	.0312	.0305
50	.0246	.0290	.0295
40	.0246	.0274	.0284
25	.0246	.0253	.0269
10	.0246	.0236	.0255
5	.0246	.0232	.0251
100	.0000	.0096	......
100	.0000	.0090	......

Although these results are not exact checks with the theoretical values, still they indicate, it is thought, that it may be possible entirely to recover the inorganic phosphorus added to these extracts; this in turn indicating in the case of wheat bran, that it is possible to make a quantitative separation of phytin and inorganic phosphorus.

Working with such extracts, however, results were always complicated by the uncertain amount of inorganic phosphorus in the extract itself. Figures representing this factor were obtained, it is true, but there was no means of proving whether they represented the actual values or not. Lack of a standard resulted in an element of uncertainty as to the above values of .0091, .0096 and .0090 for pyrophosphate in 100 c. c. of the extracts. although they are believed to be approximately correct.

It was thought that if a pure phytin could be prepared, free from inorganic phosphorus, it would, by eliminating this unknown factor, be possible to prove definitely whether a separation between phytin and inorganic phosphorus could be made quantitative.

It can be readily seen that such a preparation is attended by the same difficulties as is a quantitative determination of inorganic phosphorus in the presence of phytin.

While working on the relative solubilities of magnesium ammonium phosphate and phytin, it was found that although both substances are practically insoluble in 95 percent alcohol, a decided difference exists if the alcohol contains a very small quantity of mineral acid.

It was found further, that in 100-150 c. c. of 95 percent alcohol containing 0.2 percent of nitric acid, the quantities of magnesium ammonium phosphate commonly worked with were completely soluble, when the precipitated phosphate was shaken up with the reagent. On the other hand, phytin as precipitated from feeding materials appeared to be insoluble.

This suggested a means of separation, and at the same time a means of preparing inorganic-phosphorus-free phytin. With the latter object in view, a sample of phytin was prepared as follows:

A large quantity of wheat bran was finely ground, and extracted for several hours with 0.2 percent hydrochloric acid. The coarse bran was strained out by the use of linen, and then the extract was filtered by suction through paper in a Büchner funnel. A fairly clear filtrate was thus secured. This filtrate was precipitated with a large volume of magnesia mixture, and immediately filtered, as above, by suction. Magnesia mixture was used in order to have conditions similar to those of the regular quantitative method. The precipitate was washed thoroughly with water. This gave a very white, soft mass of fairly pure phytin. This precipitated phytin was then dissolved in a large volume of very dilute hydrochloric acid, and freed by filtration from a small residue of starchy material. The filtrate was again precipitated with magnesia mixture, and washed as before. This was repeated some 8 or 10 times. The washed precipitate was then macerated in a mortar with a small quantity of 95 percent alcohol containing 0.2 percent of nitric acid. A considerable volume of the same reagent was then added, and the whole mass shaken thoroughly in a flask until the lumps were broken up. This was then filtered again by suction, washed thoroughly with the alcohol reagent, and the maceration and filtration repeated several times. Finally the precipitate, after thorough washing with the acid-alcohol, was washed free from acid with absolute alcohol, and then dried at 50-60° C.

The product thus obtained was very white, and gave only an exceedingly faint test for inorganic phosphorus, the quantity of pyrophosphate from one gram of material being unweighable.

This test of its purity was made by precipitating the phytin in 0.2 percent nitric acid solution with lead nitrate, filtering and testing the filtrate with official molybdate solution. Tested directly, the sample would of course give no test, since the yellow precipitate would be totally suppressed by the phytin.

It is thought that separation was effected by the rapid filtration of the precipitated phytin, giving any inorganic phosphorus present, insufficient time to form magnesium ammonium phosphate, and also by the solvent action of the acid-alcohol on the inorganic phosphates present.

On this prepared phytin sample, determinations were made in an attempt to recover added inorganic phosphorus.

Using the lead nitrate method, better results were obtained than before, although exact recovery seemed impossible, due again doubtless to the slight solubility of the lead phytate formed, in the acid present, with a subsequent decomposition by the acid in the molybdate solution.

The acid-alcohol separation was accordingly tried on this prepared sample.

In each case 0.1 gram of phytin was dissolved in 100 c. c. of 0.2 percent hydrochloric acid. Inorganic phosphorus in the form of di-sodium phosphate was then added. The solution was then precipitated with magnesia mixture and ammonia. The next morning the solutions were filtered, and the precipitate washed, first with dilute ammonia, and then with 95 percent alcohol. After draining, the paper with the precipitate was placed in a flask containing 150 c. c. of 95 percent alcohol, which contained in turn, 0.2 percent of nitric acid. This flask was then shaken vigorously until the paper and precipitate were thoroughly disintegrated. The contents were then filtered through a dry filter, and 100 c. c. of filtrate placed in a beaker. This filtrate was then treated as follows:

Method I. Alcoholic filtrate was made alkaline with ammonia; filtered through a Gooch crucible; washed with alcohol; dissolved in dilute nitric acid, and precipitated with molybdate solution.

Method II. Same as Method I except that alcoholic filtrate was precipitated with magnesia mixture, instead of plain ammonia.

Method III. Five grams solid ammonium chloride were added to the acid-alcohol containing the paper and precipitate, and shaken up with the latter. The solution was then treated as in Method I.

Method IV. Alcoholic filtrate was precipitated with magnesia mixture; precipitate dissolved in dilute nitric acid, made alkaline, and precipitated direct with magnesia mixture, ignited and weighed in the usual way.

Determinations were made in triplicate. The blank on the inorganic phosphorus added, was equivalent to .0272 gram magnesium pyrophosphate.

COMPARISON OF METHODS FOR PRECIPITATING INORGANIC PHOSPHORUS FROM ACID-ALCOHOL SOLUTION

		Pyrophosphate equivalent to inorganic phosphorus added Grams	Magnesium pyrophosphate recovered Grams	Corresponding amounts of phosphorus Grams
1	Method I	.0272	.0269	.0075
2		.0272	.0266	.0074
3		.0272	.0266	.0074
4	Method II	.0272	.0266	.0074
5		.0272	.0267	.0074
6		.0272	.0267	.0074
7	Method III	.0272	.0264	.0073
8		.0272	.0269	.0075
9		.0272	.0273	.0076
10	Method IV	.0272	.0275	.0077
11		.0272	.0272	.0076
12		.0272	.0273	.0076

Since all these determinations are within the limit of mechanical error the indication is that the separation was quantitative.

The method was also used on wheat middlings. Fifty grams were extracted for 3 hours with 1200 c. c. of 0.2 percent hydrochloric acid containing 25 c. c. of 90 percent phenol. The extract was filtered through paper by suction, and varying quantities used in the determinations. Inorganic phosphorus was added, and the method followed as outlined above, the alcoholic filtrate being treated as in Method I.

SEPARATION OF INORGANIC PHOSPHORUS AND PHYTIN BY ACID ALCOHOL

No.	Pyrophosphate equivalent to inorganic phosphorus added Grams	Volumes of extract C. C.	Magnesium pyrophosphate recovered Grams	Calculated weights of pyrophosphate Grams
13	.0272	100	.0355	.0355
14	.0272	100	.0354	.0355
15	.0272	80	.0340	.0339
16	.0272	60	.0312	.0322
17	.0272	50	.0311	.0314
18	.0272	40	.0303	.0306
19	.0272	25	.0293	.0293
20	.0272	10	.0288	.0281
21	.0272	5	.0276	.0277
22	.0000	100	.0083	......
23	.0000	100	.0082	......
24	.0000	100	.0082	......

Taking into consideration mechanical errors, etc., the results are as close as could be expected.

Using Method II as detailed on page 474, some common feeding materials were tested for inorganic phosphorus. Total phosphorus was determined by the Neumann method. Determinations were made in triplicate.

These triplicate determinations were made on separate 10-gram samples of the feeding material, and not on the same solution.

TOTAL AND INORGANIC PHOSPHORUS IN CERTAIN FOODSTUFFS.

	Total phosphorus Percent	Inorganic phosphorus Percent	Average inorganic phosphorus Percent
Alfalfa	0.23	0.135 0.136 0.136	0.136
Clover hay	0.171	0.104 0.103 0.104	0.104
Corn meal	0.266	0.040 0.042 lost	0.041
Soy beans	0.547	0.054 0.054 lost	0.054
Cow peas	0.445	0.066 0.065 0.066	0.066
Oats	0.397	0.061 0.059 lost	0.060
Wheat	0.394	0.036 0.038 0.035	0.036
Brewer's grains	0.452	0.012 0.011 0.015	0.013
Distiller's grains, from corn	0.366	0.050 0.049 0.049	0.049
Rice polish	0.60	0.026 0.027 0.027	0.027

Since these triplicates represent separate samples of the feeding material, their close agreement indicates that this method is consistently workable.

The elimination, which seems to have been attained, of organic phosphorus compounds from the solution in which the inorganic phosphorus is finally precipitated, precludes the possibility of magnesium oxide or proteid phosphorus being present as an impurity in the inorganic phosphorus precipitate. Further, in those samples

which contain phytin, the acid-alcohol separation eliminates the factors (1) of suppression of the yellow precipitate by the phytin, and (2) of decomposition of the phytin by acid in the reagents used in precipitating inorganic phosphorus. Inorganic phosphorus alone appears to be present in the final solution obtained, and a clear-cut, normal, phosphorus determination results.

After considerable use of phenol in this precautionary way, we made a further test of its value on middlings, alfalfa and distiller's grains. The results were as follows:

EFFECT OF PHENOL IN INORGANIC PHOSPHORUS ESTIMATION

Foodstuff	Total phosphorus	No phenol	10 c. c. phenol	15 c. c. phenol
Middlings (1)	.762	.046	....	.046
Middlings (2)	....	.059	.061	.060
Alfalfa	....	.130	.130	.128
Distiller's grains	.811	.407	.414	.414

These determinations were made by our final acid-alcohol method. These results incline us to the belief that in these feeds, at least, there is not an appreciable splitting off of inorganic from organic phosphorus compounds by enzymes during the course of our three-hour extraction, and hence that the use of phenol is probably not necessary. In a further test of this point we got exactly the same figure, .0459 percent, for inorganic phosphorus in wheat middlings, both with and without the presence of phenol during extraction.

In another test of the same point we determined inorganic phosphorus in wheat middlings, distiller's grains and alfalfa, both with and without the presence of phenol during extraction. The differences due to the presence of phenol were immaterial. There was no evidence of benefit from the use of phenol, and hence it seems much preferable not to introduce this strong reagent into the determination.

In an attempt to shorten our provisional method we made three sets of determinations of inorganic phosphorus on wheat middlings, two on distiller's grains, and two on alfalfa, in which we sought to determine whether a precipitation with magnesia mixture should follow the separation of inorganic phosphorus from phytin in acid alcohol, or whether we might evaporate the acid-alcohol solution of inorganic phosphorus, take up with acid, and proceed with the final estimation of phosphorus in the official gravimetric way by precipitation, first with acid molybdate solution, then with magnesia mixture, and burning to the pyrophosphate.

In all cases the results by these two methods were either absolutely or practically identical, and hence we conclude that a magnesia precipitation after the acid-alcohol separation of phytin and inorganic phosphorus is unnecessary.

A similar test was made of acid and neutral molybdate solutions in the final precipitation of inorganic phosphorus, in the latter case only sufficient nitric acid being added to cause a separation of the yellow precipitate. This comparison was made by our final method, in which the phosphorus estimation is made directly after the acid-alcohol separation of inorganic phosphorus and phytin, and also by the earlier provisional method in which a magnesia precipitation intervened between the acid-alcohol separation and the phosphorus estimation. The results were practically the same, and hence our only basis for choice between these methods was ease and rapidity of manipulation.

ROUTINE METHOD

In detail the final method adopted for inorganic phosphorus in plant substances is as follows:

Pour exactly 300 c. c. of .2 percent hydrochloric acid onto 10 grams of the finely ground sample in a 400 c. c. Florence flask. Close with a rubber stopper, and shake at intervals of 5 minutes for three hours. Filter the extract through dry filters into dry flasks.

Owing to the character of the extracts from certain feeding materials, especially soy beans and oats, it may be necessary to use gentle suction toward the end of the filtration. To prevent rupture of the filter paper, a platinum cone may be used. A Witt filtering apparatus is a convenience in this work. Filtration of the extract is facilitated in many cases by the use of about one inch of fine sand in the point of the filter paper.

Measure out a 250 c. c. portion of this filtered extract, and precipitate in a 400 c. c. beaker with 15 c. c. of magnesia mixture and 30 c. c. of strong ammonia. Allow to stand over night, and filter through doubled 11 cm. S. & S. No. 595 filters, taking care to decant as long as possible without pouring out the precipitate. Then complete the transfer of the precipitate to the paper.

This filtration also may be hastened toward the end by suction, using a platinum cone to keep the paper intact.

This precipitate consists of magnesium ammonium phosphate, together with phytin, when this compound is present in the substance involved, and small quantities of variously colored unknowns.

Wash several times with 2.5 percent ammonia, and then several times with 95 percent alcohol until free from ammonia. This result may be hastened by also washing with alcohol between the

two filters. The alcohol clears up the precipitate by dissolving out a large part of the variously colored compounds other than phytin and magnesium ammonium phosphate. Allow the remaining precipitate to drain, and then spread out the inner paper on the top of the funnel, and allow the alcohol to evaporate.

When practically dry, place this inner paper with the precipitate into an Erlenmeyer flask. Add 100 c. c. of 95 percent alcohol containing 0.2 percent of nitric acid. Close the flask with a rubber stopper and shake vigorously until the paper is thoroughly broken up. If the precipitate is flaky, and refuses to break up on shaking, allow to stand in the acid-alcohol over night.

Now filter through a dry, double filter into a dry flask. Pipette out 75 c. c. of the filtrate into a small beaker, and evaporate almost but not quite to dryness. Dissolve in dilute nitric acid, and filter if necessary; then determine phosphorus in the usual gravimetric way, by precipitation first with acid molybdate solution, later with magnesia mixture, and then burning to the pyrophosphate. Reprecipitation has been found to be unnecessary.

The result as obtained above represents 6.25 grams out of the original 10 grams of material, and so to reduce to a 1-gram basis multiply by .16.

ESTIMATION OF INORGANIC PHOSPHORUS IN ANIMAL TISSUES

The most valuable method known to us for the determination of inorganic phosphorus in animal tissues has been that of Emmet and Grindley*. This method was worked out for use on muscular tissue, and for this purpose we have found it to be accurate and satisfactory. Attempts to use this excellent method with tissues other than muscle, however, showed further study of the problem to be necessary. After thorough trial we have adopted a method for our work, which is equally applicable to muscle, liver, kidney and brain, and which while giving identical results with Emmet and Grindley's method when used on muscle, has the advantage over this method of being somewhat more easily workable, and of saving one precipitation which is often necessary in the use of Emmet and Grindley's method on muscle, and which is always necessary when this method is used on liver, kidney and brain.

The difficulties encountered in our attempts to make general use of Emmet and Grindley's method for muscle, on other tissues, were in the filtration of the cold-water extracts, and in getting uncontaminated precipitates of inorganic phosphorus.

Cold-water extracts of liver, kidney and brain are not filterable by usual methods. Coagulation by boiling renders easy the filtration of liver extract, and renders possible the filtration of the extract of kidney, but does not assist materially in the filtration of the extract of brain.

Further—after finding workable methods for coagulating and filtering the extracts, the neutral molybdate precipitation of Emmet and Grindley's method gave us bulky, flocculent, organic precipitates, especially in the case of liver, kidney and brain, which by obscuring the formation of the yellow precipitate, rendered impossible an accurate judgment as to the amount of acid necessary to the completion of the precipitation. These bulky, flocculent precipitates redissolve in ammonia, and reappear in the precipitate with magnesia mixture. The possibility of adding phosphorus or magnesia to the pyrophosphate through their presence in the above-mentioned flocculent, organic precipitates, contributes another item of uncertainty and possible inaccuracy to the use of this method when we attempt to apply it to liver, kidney and brain.

*Journ. Am. Chem. Soc., Vol. 28, p. 25.

In our study of methods of preparation of the water-extract for filtration, we found that boiling and treatment with ammonium sulphate would render the extracts of any of these tissues readily filterable.

After a trial of various methods on brain, we found most satisfactory results obtainable by boiling the extract for a few moments, the exact time being immaterial, then adding ammonium sulphate in solution, and continuing to boil for about ten minutes.

The various difficulties of precipitation and filtration, incident to the preliminary molybdate precipitation, were obviated by direct precipitation of the inorganic phosphorus, from the coagulated and filtered extracts, with magnesia mixture. This gives us a precipitate of approximate purity, results in a very great saving of time in filtration,and obviates the possibility of hydrolysis of organic phosphorus compounds by the nitric acid used in precipitation with ammonium molybdate.

This precipitate with magnesia mixture is dissolved and reprecipitated, first with official acid molybdate solution, and then again with magnesia mixture in the usual way, and the phosphorus weighed as the pyrophosphate.

The essentials of the new method are (1) extraction of the inorganic phosphates with hot water, (2) boiling the extracts with ammonium sulphate to render them filterable, (3) direct preliminary precipitation with magnesia mixture, and (4) a number of important mechanical details of procedure.

Our first work on this problem was an attempt to use Emmet and Grindley's method for muscle, on liver, kidney and brain. We proceeded as follows:

The muscle extract was prepared with cold water according to Grindley*.

The liver extract was prepared in the same way, but was heated on the steam bath in order to render it filterable through paper.

The kidney extract was prepared in the same way as the liver extract, but was not filterable through paper. This solution was filtered through sand in the cone of a linen filter such as is used in crude-fiber determinations.

The brain extract contains practically the whole of the brain substance, the addition of water simply diluting the paste. It was not filterable hot or cold, through paper, linen or sand. This solution was rendered filterable by bringing to a boil, adding ammonium sulphate, and continuing to boil for ten minutes. It was then passed through sand on linen.

*Journ. Am. Chem. Soc., Vol. 27, p. 658.

We now had (1) a cold-water extract of muscle, (2) hot-water extracts of liver and kidney, and (3) a hot-water-ammonium sulphate extract of brain.

Measured portions were concentrated by boiling in order to reduce the bulk and to coagulate proteids, and were then filtered through paper, and washed with water, but not without difficulty in the case of liver, kidney and brain.

Proceeding by the method of Emmet and Grindley, we treated the extracts with neutral molybdate solution and 3 c. c. of 1.20 nitric acid, as specified, to effect the separation of the yellow precipitate.

In the case of liver, kidney and brain, it was found that 3 c. c. of nitric acid were insufficient. Two cubic centimeters in addition, five in all, were found necessary, because of the abundance of organic matter in these solutions, and 10 grams of ammonium nitrate, instead of 5 grams as specified by Emmet and Grindley, were found necessary with the brain, where we had added ammonium sulphate.

The results were not satisfactory. The liver, kidney and brain extracts gave abundant flocculent precipitates, greenish colored with the liver, nearly white in the case of the brain, and of an intermediate grayish color with the kidney. These contaminations so masked the yellow precipitate that accurate judgment as to the completeness of the precipitation was impossible.

The precipitates were filtered out, and reprecipitated with official acid molybdate solution. The contaminations persisted in all cases except with muscle.

The yellow precipitates were redissolved, and precipitated in the usual way with magnesia mixture.

These last precipitates were obviously impure. With the brain an abundant, white, flocculent contamination was present, while with the liver and kidney the precipitates were highly colored.

The results with muscle were satisfactory.

The pyrophosphates from liver, kidney and brain were boiled with nitric acid, and precipitated once more with magnesia mixture, but the results were of doubtful value.

We next attempted the precipitation of inorganic phosphates with dilute solutions of calcium and ferric chlorides. The gelatinous precipitate was difficult to wash, and probably on this account, gave slightly higher results on muscle than did Emmet and Grindley's method.

The direct precipitation of the concentrated cold-water extract of muscle with magnesia mixture was now tried, followed by precipitation, first with official molybdate solution,

and then with magnesia mixture, and this gave results identical with others obtained by the Emmet and Grindley method.

This method was therefore given a careful trial. The points which we sought to determine were (1) whether or not the use of heat and ammonium sulphate gave the same inorganic phosphorus content in the extract as Grindley's cold-water extraction, and (2) whether or not the direct precipitation with magnesia mixture effected a complete precipitation of the inorganic phosphates without bringing down other phosphorus compounds to contaminate the pyrophosphate.

COMPARISON OF METHODS FOR THE ESTIMATION OF INORGANIC PHOSPHORUS IN MEAT

	Grams magnesium pyrophosphate per gram fresh substance		
	Emmet and Grindley's Method Precipitated (1) with neutral molybdate and minimum of acid, (2) with official acid molybdate, (3) with magnesia mixture, and (4) with magnesia mixture	Magnesia Method Precipitated (1) with magnesia mixture, (2) with official acid molybdate, and (3) with magnesia mixture	Acid-Alcohol Method Precipitated (1) with magnesia mixture, and dissolved in acid alcohol, (2) with magnesia mixture, (3) with official acid molybdate, and (4) with magnesia mixture
Muscle sample No. 1 Cold-water extract	.0049 .0049 .0047	.0051 .0051 .0050	.0048 .0048 .0047
Muscle sample No. 1 Boiled with ammonium sulphate	.0050 .0051 .0049	.0050 .0050 .0050	.0049 .0049 .0051
Muscle sample No. 2 Cold-water extract	....	.0056 .0053 .0054	.0053 .0053 .0054
Muscle sample No. 2 Hot-water extract	....	.0056 .0056 .0056	....
Muscle sample No. 2 Boiled with ammonium sulphate	.0054 .0054 .0054	.0055 .0055 .0054	....
Liver sample No. 1 Hot-water extract; ammonium sulphate added, then concentrated by boiling	....	.0049 .0049 .0050	.0048 .0049 .0049
Liver sample No. 1 Boiled with ammonium sulphate	....	.0047 .0049 .0048	....

The above table sets forth our results in this work. The figures represent the weight of pyrophosphate from the inorganic phosphorus in one gram of meat.

In making these determinations the amount of meat represented by each precipitate was about three grams.

With a cold-water extract of muscle sample No. 1, we compared Emmet and Grindley's method, with our magnesia method, and also with our acid-alcohol method, which we have adopted for vegetable substances.

The triplicates agree almost exactly, and the determinations by the different methods also agree, the differences being well within the limit of legitimate error of work. This excellent agreement in results by three different methods, shows that the inorganic phosphorus of flesh is a definite part thereof, and that it is susceptible of accurate estimation.

The agreement three times each by three well-considered methods also shows that they are all probably correct.

The acid-alcohol method is as long as the Emmet and Grindley method, and was included in this trial because its agreement with the other methods would not only strengthen them, but would also tend to sustain our method for inorganic phosphorus on vegetable substances. The results fulfill these desired conditions.

The magnesia method is decidedly the best of the three, however, because of the aforementioned advantages of brevity, purity of precipitates, and ease and certainty of manipulation.

A second extract of muscle sample No. 1 was prepared by boiling with ammonium sulphate, for the purpose of ascertaining what effect, if any, this salt might have in our estimation of inorganic phcsphorus in other tissues, especially in kidney and brain, where we have found ammonium sulphate especially useful in the preparation of the extracts.

The close agreement of our triplicates and the very close agreement of the results by each of the three methods, and the agreement of determinations on this hot-water-ammonium sulphate extract with the equally satisfactory results on the cold-water extract show that ammonium sulphate is without effect on the estimation of inorganic phosphorus, due regard being given, of course, in the Emmet and Grindley method, to the sulphuric acid radical which this salt introduces into the solution.

With a second sample of muscle we compared the magnesia method and the acid-alcohol method on a cold-water extract, with the magnesia method on a hot-water extract, and with the Emmet and Grindley, and the magnesia methods on a hot-water-ammonium sulphate extract.

The three methods again checked remarkably well, and there appears to be no difference in the inorganic phosphorus contents of the cold-water, the hot-water, and the hot-water-ammonium sulphate extracts.

With a sample of hog liver we compared two methods of use of ammonium sulphate. In one case the tissue was boiled with the sulphate, as in the preparation of the extract of brain and kidney, while in the other the sulphate was added to the filtered hot-water extract, and was present only during the concentration of the extract by boiling.

The magnesia method once more gave identical results with those from the acid-alcohol method, and the presence of ammonium sulphate was again found to be without demonstrable effect, either on the extraction or the estimation of the inorganic phosphorus.

In making a final comparison of the three methods, it may be said that the amounts of phosphorus found by the three are practically identical, but with slightly higher results, just perceptible, and well within the limit of error of work, in favor of the magnesia method.

The details of our magnesia method for the estimation of inorganic phosphorus in muscle, liver, kidney and brain are as follows:

PREPARATION OF SAMPLES

The animals whose tissues are to be compared must be killed in the same way, and should be quickly and thoroughly bled in order that the blood content of the tissues may be the result of natural conditions, rather than differences in method of killing, such as varying lengths of time between stunning and bleeding.

In order to get a definite product for analysis, the brain should be freed from its vascular investing coats by carefully stripping these away with forceps.

The gall bladder should be removed from the liver, and also such tough connective tissues at the base of the organ as would interfere with the free grinding of the functional liver tissue.

The kidneys are removed from their capsules; the fat, blood-vessels and ureter are removed with scissors from the hilus, and the interior of the organ is opened and freed from contents.

The muscular tissue is freed from superficial fat and from tendons.

All work is done as promptly as possible, with all possible precautions to prevent evaporation.

The tissues are prepared for sampling by grinding with an "Eclipse" grinder. An electric motor attachment is a great saver of labor, and by facilitating the work, helps to minimize loss of moisture by evaporation.

The materials are ground three times, with careful mixing between grindings, and samples are placed in glass jars which have screw tops lined with rubber. The bottles of ground meat are then frozen up as quickly as possible, and kept in this condition until the determination can be started.

PREPARATION OF EXTRACTS

Weigh by difference from closed weighing bottles, 20-gram portions of liver, kidney or muscle into 400 c. c. beakers. In the case of brain, weigh out likewise about 20 grams, but divide it between two 250 c. c. beakers.

Beat up in a little cold water, to separate the particles of meat; add 200 c. c. of boiling water for muscle, liver and kidney, and 100 c. c. of the same for each half of the brain sample, and bring to boiling. Add ammonium sulphate in solution equivalent to 1 gram for each 10 grams of muscle, liver and kidney, and to 4 grams of the same for each 10 grams of brain, and continue to boil for 10 minutes.

Remove from the flame; allow to settle for a moment, and decant the boiling-hot liquid onto 18 cm. folded paper filters, for muscle liver and kidney, and onto sand in an 18 cm. linen filter in the case of brain.

Add 100 c. c. of boiling water to the liver, kidney and muscle remaining in the beakers, and in the case of brain 50 c. c. of 0.1 percent boiling ammonium sulphate solution to each half of the sample.

Stir for about 8 minutes in the case of liver, kidney and muscle, and for about one minute with brain, and decant the liquid onto the filter. Repeat this addition of 100 c. c. portions of water, (50 c. c. of 0.1 percent ammonium sulphate with brain), stirring and decanting five times; repeat three times more with 50 c. c. portions of boiling water with liver, kidney and muscle, and with 25 c. c. portions of 0.1 percent ammonium sulphate solution with brain. With the eighth portion of water, (or 0.1 percent ammonium sulphate), throw the entire contents of the beaker onto the filter, and wash with hot water from a wash bottle, with liver, kidney and muscle, and with hot 0.1 percent ammonium sulphate solution for brain. The two portions of brain extract are combined. The extracts of all the tissues are then made up to 1000 c. c.

It is especially important that the brain extracts be kept and handled boiling-hot. If the sand filter clogs during the filtration, this process may be greatly facilitated by lightly scratching over the surface of the sand with a stirring rod, taking care not to touch the linen.

It is not advisable to attempt to handle more than 10 grams of brain in one beaker, on account of the necessity of completing the filtration promptly while the solution is hot.

DETERMINATION OF INORGANIC PHOSPHORUS

Measure out 250 c. c. portions of the extract into 400 c. c. beakers. Evaporate to 50 c. c. by gentle boiling; filter while hot, and wash with boiling water. Cool, and add 10 c. c. magnesia mixture, stirring freely; allow to stand 15 minutes, and add 10 c. c. of ammonia, specific gravity .90. Cover, and allow to stand over night.

On the next morning filter, and wash the precipitate with 2.5 percent ammonia water. Dissolve the precipitate on the filter paper with dilute nitric acid into the same beaker in which the first precipitation was made, and wash the papers thoroughly with hot water.

Render the resulting solutions nearly neutral; add 5 grams of ammonium nitrate; heat to 65° C.; add 50 c. c. of official acid molybdate solution, and keep contents at 60°, stirring frequently, for 2 hours.

Then continue in the usual way for the gravimetric estimation of phosphorus as the pyrophosphate.*

Each 250 c. c. of the extract will, of course, represent one-fourth of the original sample, and therefore will contain the inorganic phosphorus from about 5 grams of fresh substance.

SUMMARY

Inorganic phosphorus in plant and animal tissues appears to be susceptible of practically as accurate quantitative estimation as in ordinary inorganic analysis.

The principle of our method of inorganic phosphorus determination in plant substances is (1) extraction of the inorganic phosphorus with .2 percent hydrochloric acid, (2) precipitation with magnesia mixture, nucleinic acid being removed in solution, (3) dissolving the inorganic phosphorus out of this precipitate by the use of acid-alcohol, phytin remaining behind with the paper, (4) evaporation of the alcohol from the acid-alcohol solution of the inorganic phosphates, followed by solution of the phosphates in acid and a gravimetric estimation of phosphorus in the usual way by

*Bul. 108, Bur. Chem., U. S. Dept. Agr.

precipitation, (5) first with official acid molybdate solution and then, (6) with magnesia mixture, and finally (7) burning to pyrophosphate.

Where necessary to prevent enzyme action phenol may be used in the extractive reagent.

This method is somewhat tedious but is clean-cut, workable and exact.

The method for animal substances is in brief (1) extraction with boiling ammonium sulphate solution, (2) filtration, concentration by boiling, and precipitation with magnesia mixture, (3) a gravimetric estimation of phosphorus by precipitation, first with official molybdate solution, then (4) with magnesia mixture, and finally (5) burning to the pyrophosphate.

This method is equally applicable to muscle, liver, kidney and brain.

SPRAYING MACHINERY

OHIO
Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., APRIL, 1910

BULLETIN 216

The "Old" and the "New."

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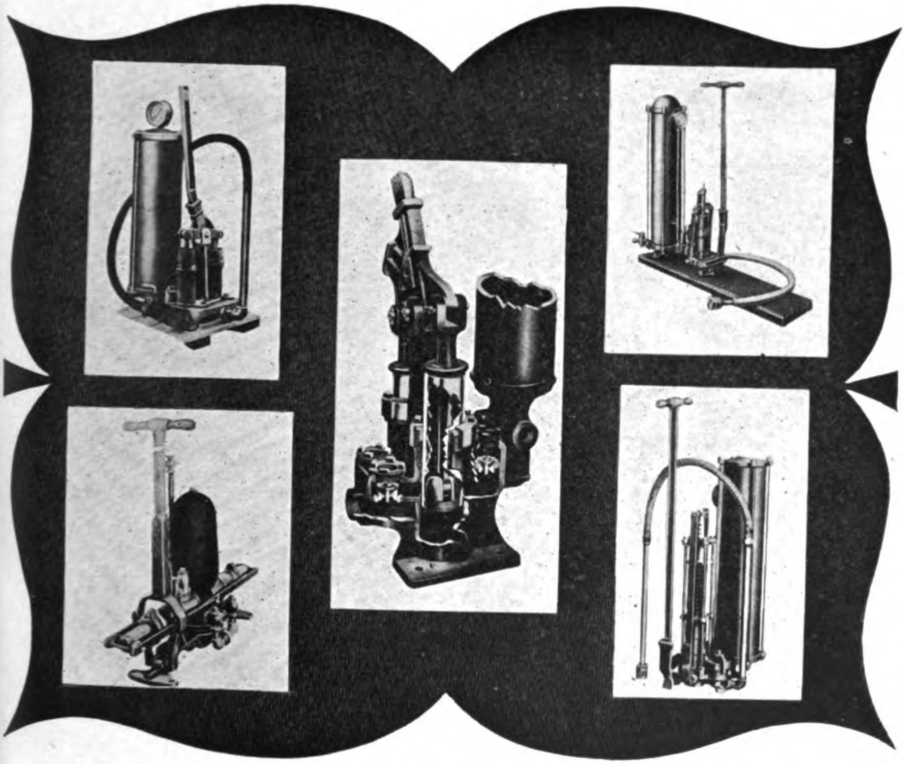


Five types of large hand pumps

Hardie
Brown

Goulds

Deming
Bean

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 216 APRIL, 1910

SPRAYING MACHINERY

BY W. H. GOODWIN

Spraying machinery has become of special importance during recent years through the interest in fruit growing aroused among farmers and fruit growers in general. Experiments carried on by this Station have proved beyond a doubt that apples and other fruits of excellent quality can be profitably raised in Ohio. The unusually high price which good fruit has commanded during the past five years has tended to attract many who ordinarily would not consider orcharding as a vocation.

The fact that Ohio has a large amount of land which is unsuited to farming but will make excellent orchard land, and that the northern part of Ohio is tempered by the Great Lakes, has also stimulated fruit growers to make use of what nature has provided for them. The intense competition of the Western states in shipping fruit into a fruit-growing region and selling it where poor, home-grown fruit could not be marketed, has aroused a feeling that Ohio orchardists could raise fruit that was just as good, and they have demonstrated that this is true. These orchardists only needed to have their pride stirred up to set them at work to duplicate or excel western achievments.

Because so many people are totally unacquainted with spraying operations and spraying machinery, the preparation of this bulletin has been undertaken. It is the hope of the author that it may aid many of the uninitiated in the selection of a machine which will do what is desired of it.

Spraying machinery has been passing through a period of transition during the last decade, and pumps used for different kinds of spraying are rapidly becoming special purpose machines, designed to spray some certain crop or series of crops, which are treated in a similar manner. For example, this evolution has developed a traction machine of large capacity which will furnish liquids at high pressures to do grape, field and potato spraying thoroughly with a minimum of expense for labor and material. This is usually a two-wheeled, traction-power type of machine, in which the power is transmitted from the wheels by gears, chains, eccentrics, or cams, and the horse does the work instead of a man at the end of a pump handle.

Sometimes a man has made the acquaintance of some particular make of machine and knows its little faults so well that it may be better for him to retain this machine rather than purchase some simpler, less troublesome type of pump. On the other hand, in the present period of evolution in spraying machinery, it will often pay a man well to discard his old favorite for some more modern, more efficient type of machine which is better suited to his special line of work and better adapted to the particular conditions existing in his locality.

FACTORS TO BE CONSIDERED IN CHOOSING A SPRAY PUMP

Capacity, which involves.....	Size Weight
Simplicity, which involves ...	Accessibility of parts Ease of repair
Durability, depending upon..	Quality of material Kind of material Workmanship Correct mechanical principles and designs Strength Weight
Cost, determined by.........	Capacity of pump Type of pump Amount of labor involved in manufacturing Material used Quality of material

Capacity. A pump of larger capacity than is actually needed will always prove more satisfactory than one which falls short of the demands made upon it. As trees and orchards increase in size, the importance of having a machine which will enable the fruit grower to cover a considerable area quite rapidly, becomes apparent. The grower must either purchase a new machine of larger capacity or look ahead at the outset, and provide for the future. Four acres of good bearing orchard is worthy of a power sprayer if the best

results are desired, and nothing of smaller capacity than a large hand pump should be considered. A larger or smaller orchard will require a pump proportionately larger or smaller, but there is a limit for even the largest machines, and twenty acres of large trees is about all one large power sprayer was ever designed to spray.

Simplicity. Spray pumps should be as simple as possible, with a minimum of parts which ordinarily require attention. These parts should be easily replaced when worn, and should not be expensive when replacement becomes necessary. The ideal sought demands, *ease of repair*, a minimum of parts, and these *readily accessible*, when worn, or not working properly. Leaky packing, clogged valves, worn out valves, valve seats, cylinder liners, and plunger packings or cups must all be considered before choosing a pump that will fulfill its mission and serve the purpose for which it was purchased.

Durability. On the *quality* and *kind* of *material*, the excellence of the *workmanship*, together with *weight* and *strength* depends the *durability* or lasting qualities of the machine. Good design is also an important factor. *Cheapness* quite often means that inferior material has been used, and that inefficient or negligent laborers, who slight their work by accident or design, have been employed in the pump's manufacture.

Designers and builders of pumps often seem unwilling to adopt new ideas or better designs, and continue to build the same type of machine that they did ten or twelve years ago. Such machines will squirt liquid after a fashion, but they do not give the purchaser the returns desired with a minimum of expense for labor and repairs.

Some machines were never intended by their designers to pump gritty spray solutions, oil emulsions, caustic solutions, or acid oils in emulsion form, and consequently will not prove satisfactory. The *efficiency* of a pump depends largely upon the construction of its valves, valve-seats, plunger, cylinder and stuffing box, if built with the last. Air chambers are also very important, hence these subjects will be taken up under separate heads.

The *body* or *frame* of the pump should be heavy and strong enough to withstand hard usage and excessive strain. Bearings are often too short, gears too narrow and too light in weight, oil cups are omitted where they are needed, and the frame upon which the machine is mounted is so light that it is warped and buckled at every stroke of the pump.

Air Chambers are often omitted on small pumps and some large machines are equipped with very small ones. A barrel pump is greatly improved by the addition of an air chamber five or six inches

in diameter and about two feet long. Intake and hose supply-pipes must be from a point near the bottom of the chamber or the value of the resilent column of air is lost. The value of an air chamber lies in the even pressure obtained, in the taking away of the heavy shock upon valves, and of the sudden strain often put on other parts of a pump. A good air chamber also eases the labor of the man at the handle of the pump or of the engine which is furnishing the power. The liquid in the air chamber is often unagitated unless some provision in design has been made so that the opening of a nozzle cut-off agitates the liquid contained in the air chamber, in addition to the agitation caused by the supply of liquid being forced into the chamber.

Cylinders. Of cylinders we have several types, but no spray pump cylinder should be made of cast iron or steel, except for spraying miscible oils and lime-sulfur solution. Brass tubing of heavy weight and threaded to fit the cylinder head is quite a common design. Some makers use a brass tubing cylinder clamped between the cylinder heads. Others use a solid cast chamber with some form of a brass liner or cylinder inside of the cast iron one. The most durable and the one least affected by spray solutions is undoubtedly the heavy, cast iron cylinder enameled with porcelain. The chief obstacle to the use of such a cylinder has been to get an even coat of enamel on the inside of the machined cylinder-casting, or a plunger-packing or cup which would have sufficient resilency to adapt itself to the uneven wall of the cylinder. Some of the manufacturers seem to have solved this problem in a satisfactory way, while others claim it is but a partial success when used in the type of machine which they manufacture.

Valves. Kinds of valves are almost too numerous to mention if one takes into account the variations in each class. We may divide them into four classes: ball, poppet, swing-check and steam-check valves. For the first, three materials are used: rubber, steel and bronze, the latter material being of course the most durable for all-round work. Of the styles of poppet there are many which may be classified as follows: plain, square-faced poppet valves with rod-guide to hold them in position as in Fig. 1 of the plate showing valves. Fig. 2 shows how uneven is the wear on such a valve. Fig. 3 shows a plain poppet valve with wing-blades to right it instead of a rod. Fig. 5 is a bevel-faced, wing-guided poppet valve, which approaches a large ball valve in durability and efficiency, when it is made so that it will rotate. Fig. 4 shows a modified form of a wing-guided poppet valve, with a rubber or leather ring to improve its efficiency in helping to retain the liquid above it. Figs. 6, 8 and 10 are ball valves.

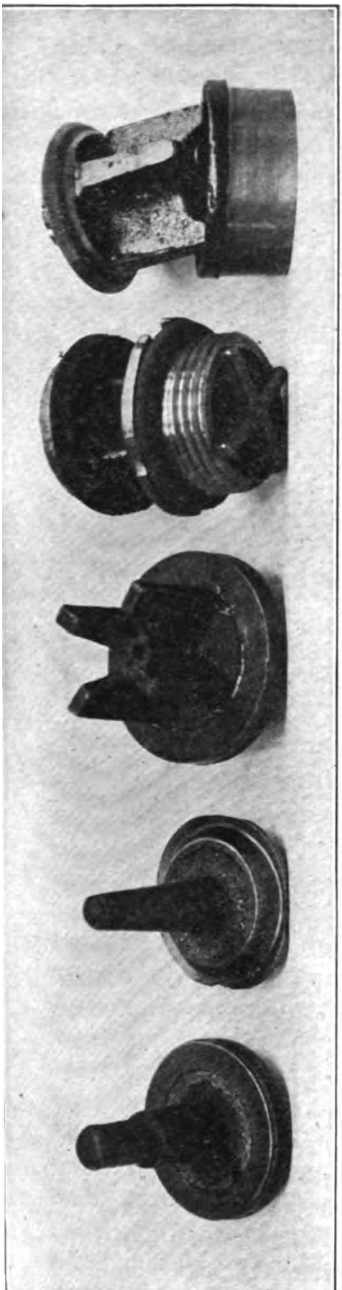


Fig. 1 Fig. 2 Fig. 3 Fig. 4 Fig. 5

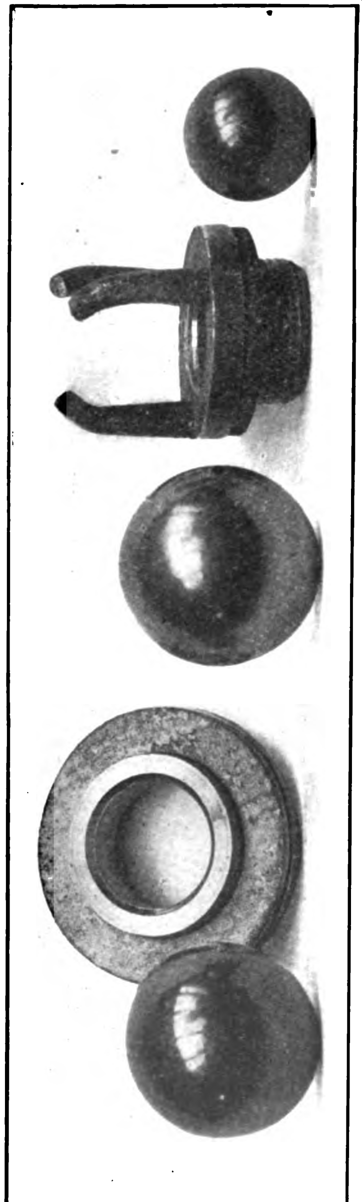
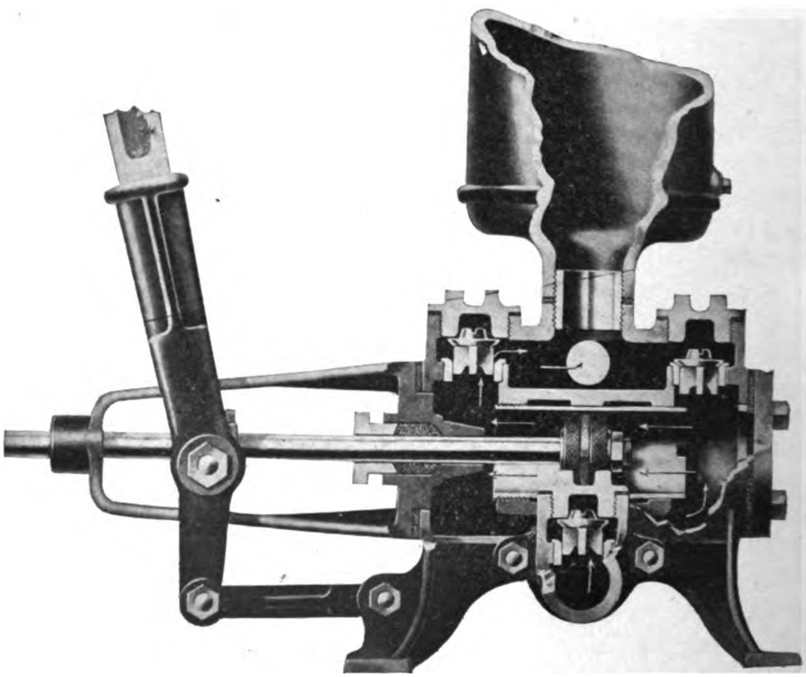


Fig. 6 Fig. 7 Fig. 8 Fig. 9 Fig. 10

PLATE SHOWING VALVES

Figs. 6 and 8, are about the desired size to give the maximum o durability and efficiency. The minimum size, shown in Fig. 10 should not be less than three-quarters inch in diameter, and the upward range may extend to one and three-eighths inch in diameter, as in Fig. 8, for the maximum size, in large power pump. Smal hand pumps may have ball valves as small as one-half inch in diameter. Poppet valves should be much larger in proportion to the amount of liquid passing through them than should the bronze ball-valves. It is well to remember that, when the pump is running the valve becomes as much lighter in weight as is the weight of the amount of liquid it displaces, hence a much heavier valve can be used than a novice might suppose.



Goulds double acting pump showing arrangement of parts.

Swing check and steam check valves are types designed for use in water and steam pipes. Both types work well in spray pumps when they are new, but their lasting qualities in a spraying machine are yet to be demonstrated. A flat face in any valve wears unevenly and makes a leaky valve when in combination with a flat valve-seat. Threads or waste sucked through the strainer often lodge across the square edge of the valve-seat and hold grit, hence the desirability of having bevel edges in valve-seats so that such material will not catch.

Valve Seats. Valve seats are built to receive the type of the valve used, and are made correspondingly cheap or costly. Iron valve-seats are common, and are usually found in ordinary well-pumps. Some few makers use a rubber or leather ring as a secondary seat, which prevents back flow, through its elasticity, when the weight of the liquid or the pressure above holds the valve down. One company has equipped a pump with hard rubber valve seats, but the majority of the manufacturers use a removable brass valve-seat. Strange to say, no company, as far as I know, seems to have tried to build valve-seats of the harder, non-corrodible alloys—that is, those not affected by spray solutions. In valves, a large part of the wear is on the valve-seat, especially in the case of the bronze-ball types. The ball may wear some, but constant turning keeps it a perfect sphere, while the valve-seat is hammered and worn away at every stroke of the pump, making plain the desirability of using a harder metal for a valve-seat than is used for the ball. I think that any man who has had experience with pressure pumps will also concede that a large ball-valve is the most efficient and durable type made, especially for gritty solutions such as many of the spray mixtures are known to be. Figs. 7 and 9 show valve-seats and the accompanying balls are on the left and right of the valve seats.

Plungers. Plungers are fitted with various types of packing. Very few pumps are equipped by their makers with poor packing, but leather hardens so rapidly that it is almost worthless as a packing for a spray pump, and hence should not be used for plunger-cups when other material can be obtained. The following materials are used for plunger packings: hemp, candlewicking, steam packing, paraffine canvas, cotton cloth reinforced with rubber, and various other packings which go under trade names. Most of the packings are treated with oils, graphite or paraffin, but this does not include those in which rubber has been incorporated. Plungers are usually designed to carry a special kind of packing and they work better with that kind of packing than with almost any substitute. A packing that is cheap, easily renewed or replaced, and that will last for a considerable period of time without wearing away so rapidly that it requires constant attention to keep it in shape, is the most desirable.

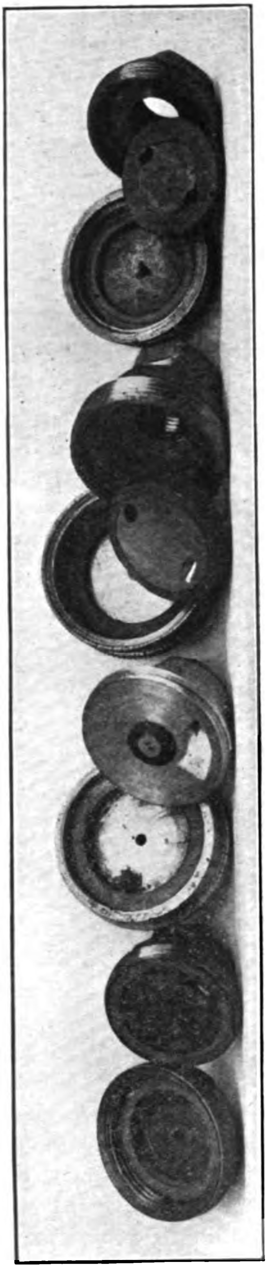
Agitators. Agitators are a frequent source of trouble in spraying outfits, especially in power machines. Swinging paddles usually pose as agitators or long rotary types are used in the bottoms of round tanks or barrels. These work very well in small tanks or barrels but are a decided failure in large tanks. The sliding agitator is the type used ordinarily in most power machines. Connections of the agitators to power are made in various ways but the principle is much the same

in different makes. The amount of power required to operate such an agitator is enormous, in proportion to the agitation one gets in an ordinary tank. Propellor agitators are much more efficient than other types because of the higher speed at which they may be run, their durability, simplicity, light weight, small size, and neat appearance, all being in their favor; besides possessing these qualities, they agitate the spray liquid thoroughly and require less power to operate them than any of the large, sliding types of equal efficiency. Jet agitators are often used on small hand pumps, but they are always inefficient and give very little agitation. A jet agitator, properly constructed would give fair agitation, but I know of none which utilizes the shape of the tank in helping to agitate the solution.

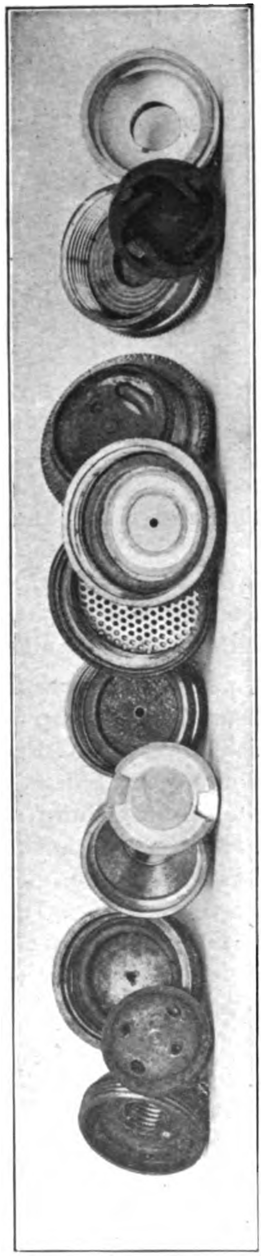
A number of hand-pumps are patterned after the ordinary water force-pump. With these the stuffing box is the source of so much friction that barrel pumps of this type should be avoided. Simpler types of pumps, without a stuffing box, should be selected. Plungers with a plunger-cup, or inside plunger-packing, require less power to operate them. Outside plunger-packing, or a stuffing-box on the outside of the plunger, is another method used in order to facilitate packing and obviate trouble. Double-acting pumps must necessarily have the stuffing box and plunger-packing too, but some of the strongest and most durable power pumps are of this type. Of the two latter types I have no particular choice, as each has its merits, and each requires about the same amount of care. The simple, single-acting pump with a plunger-cup or plunger-packing on the outside or inside, requires less attention than any of the other types and is preferable to the other types.

Supply tanks. Supply tanks are of various shapes and sizes, but the round-bottom tank is most used because it is easy to build and easily kept tight by merely tightening a few nuts on the clamp-rods. Hoop tanks always dry out and give trouble. Square, rodded tanks are very good but require more tightening of rods when they become leaky. They have some points of superiority in case the ordinary types of agitators are used, since these will agitate the solution better when it is driven into the corners of a square tank.

Nozzles. Nozzles are often a source of considerable trouble to the operator of a spraying outfit. Bordeaux nozzles throw an uneven flat spray, which is too coarse for most spraying. Vermorel types with medium caps throw a narrow-angle, fine spray, but they are of small capacity, are always catching on limbs and frequently clogging. Pressure at the nozzle-cap is also much reduced by the narrow orifices and tortuous channels through which the liquid must pass. Nozzles utilizing the principle of the whirl caused by the liquid entering from the sides of the whirling chamber, do not reduce so much the pressure



Spramotor Co's. Large Type. Friend Mfg. Co's. Aluminum Large Type. Hardie Mfg. Co's. Large Type Goulds Mistry Jr.



Goulds Mistry Jr. Four-Hole. Winkle Nozzle. E. C. Brown & Co's. Atoma Nozzle. Bean Spray Pump Co's. Large Type.

NOZZLES

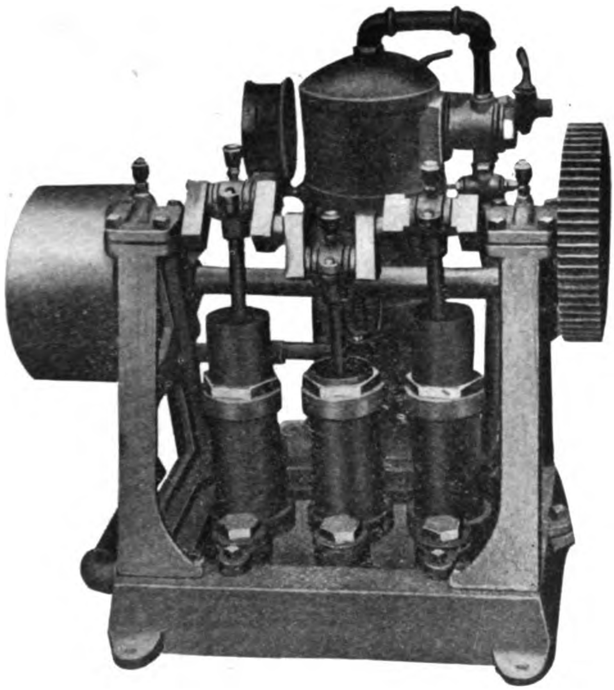
and force, and give a broader, finer spray, without reducing the speed of the liquid as it passes through the nozzle cap. They also allow the use of much larger orifices and abolish the trouble of nozzles catching on limbs. This brings us to the large types, which are made by a number of the companies and, so far as I know, all of these types of large nozzles are good.

FACTORS WHICH TEND TO MAKE A NOZZLE THROW AN EVEN SPRAY

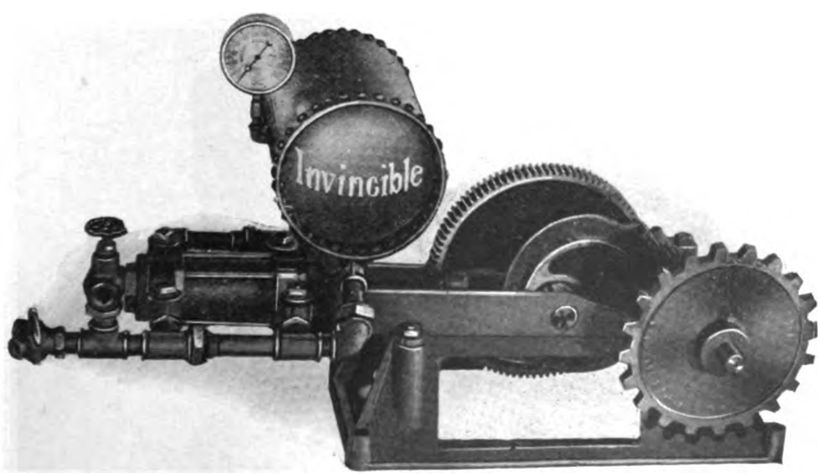
One fault that manufacturers seem to have overlooked is the tendency of the large type nozzle to throw the bulk of the spray in one quarter of the circle. This may be overcome by making more supply holes through the plate or top of the nozzle under the whirling chamber. Nozzles with four holes through the plate, instead of two, throw an almost perfectly even circle of spray. These holes make the supply of liquid come from four quadrants instead of from one or two quadrants, and even up the spray passing out through the nozzle cap. The illustration of large nozzles shows one with a four-hole supply and another with four jetties around the holes and on the sides of the whirling-chamber which give the whirl to the liquid and make a fine, even spray, especially with the high pressure obtained from power outfits. Large-type nozzles are made by the following companies:

American Sprayer Co., Minneapolis, Minn.
Bean Spray Pump Co., Berea, Ohio.
E. C. Brown Co., Rochester, New York.
Deming Co., Salem, Ohio.
Field Force Pump Co., Elmira, New York,
Friend Mfg. Co., Gasport, New York.
Goulds Mfg. Co., Seneca Falls, New York.
Hardie Mfg. Co., Hudson, Mich.
F. E. Myers & Bro.: Ashland, Ohio.
Spramotor Co., Buffalo, N. Y.
Wm. Stahl Sprayer Co., Quincy, Ill.
Geo. J. Winkle, Seneca Falls, New York.
Niagara Sprayer Co., Middleport, New York.

On an ordinary power outfit, two leads of hose should be used, a larger number seldom being of any great advantage in orchard work. The lead of hose to the man in the tower need be only fifteen feet long, while the man on the ground should have at least thirty feet, and forty feet of hose is not too much when spraying large trees. On hand- or barrel-pumps one lead of twenty-five or thirty feet in length does very well for all spraying work, or two leads of that length may be used when two men are on the ground.

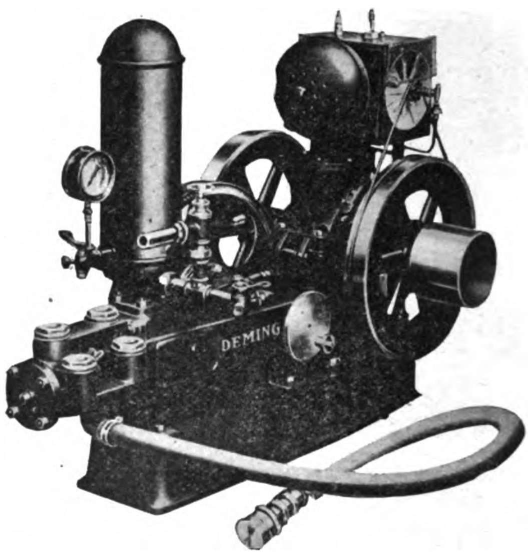


A pump which may be used with any engine of sufficient horse-power.
Hardie Mfg. Co.

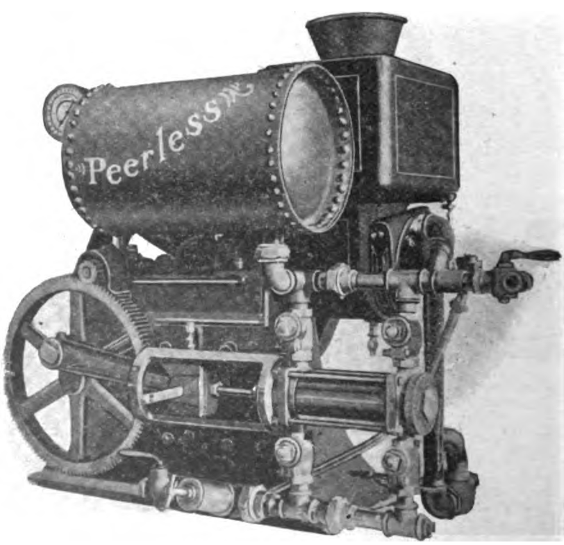


An independent pump that can be attached to any engine, belt-drive preferable.
American Sprayer Co.

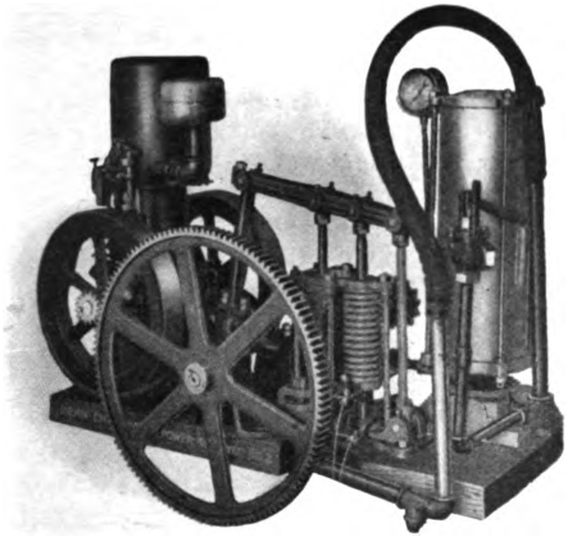
High pressure hose with long hose couplings and good hose bands are a necessity in spraying, for ordinary hose bursts under the high pressure to which it is subjected and short couplings are always making trouble. Half-inch high-pressure hose is most used, but three-eighths inch is also good and is not so heavy. The latter is harder to get connections for, when they are lost or broken, and may prove a little small in capacity when one uses three large-type nozzles on the end of a spray-rod.



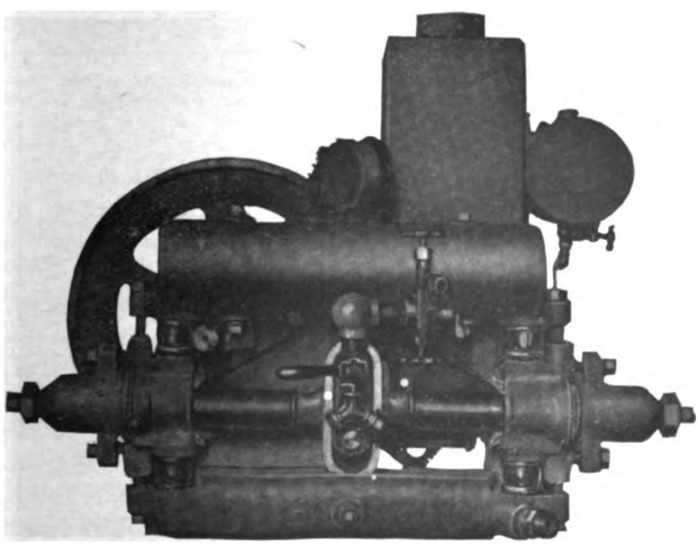
Deming double acting power pump with cast base and brass working parts.



American Sprayer Co's. double-acting power pump with rod-clamped brass cylinder and brass working parts.



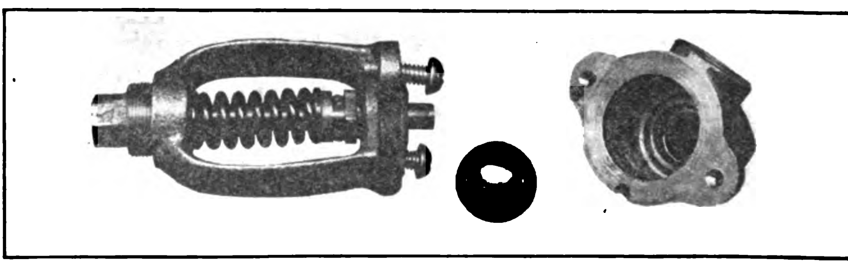
Bean power pump with one large diameter, single acting, porcelain lined cylinder and a patented spring attachment.



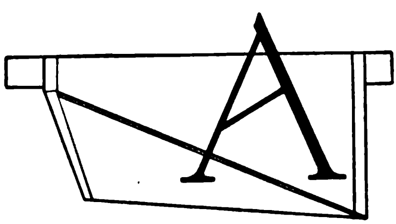
Friend power pump with two single-acting cylinders of small diamete..

CUT-OFFS between hose and rods are of many kinds and are more often too small than too large. They are troublesome to turn when too small and soon become leaky. The box type cut-off illustrated at the beginning of this paragraph is among the best.

Rods are made of iron pipe, brass pipe, and bamboo with a brass or aluminum tube running through the hollow bamboo. Aluminum-lined bamboo rods are lighter than any of the others and when properly reinforced at the ends are as strong as any bamboo rod put out. In length the rods should not be less than eight feet. Ten-foot rods are preferable and twelve-foot rods are often a necessity in order to reach the tops of high trees. Longer rods are not often needed, and are cumbersome and hard to handle on account of their length.

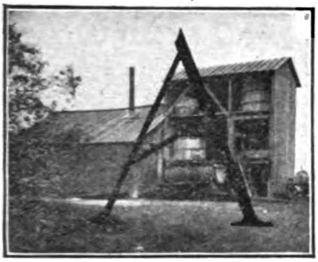


Hardie escape valve showing compressor, spring, ball, and seat. A neat, reliable and durable type of safety relief valve.



AN excellent strainer can be made by fastening a piece of fine mesh brass screening in the frame of a box and at an angle of about 30 degrees, as shown in the illustration of the initial letter of this paragraph. One end is sloped in so that the strainer may be lifted out by the end without sticking in the opening of the tank. The sloping screen is kept free from material through the action of the liquid, which is poured on the upper end of the screen and carries the material that will not pass through to the lower end. This keeps the screen clear for straining the liquid as it comes from the supply tank. This strainer may be made double by placing another similar one above the first, but with the screen sloping in an oposite direction. This is one of the simplest, most durable and efficient types of strainers, which can be easily made and repaired.

One of the necessities of the spraying business is a *good strainer.*



A MOST important thing is a good, convenient mixing plant. I have not seen a half dozen good mixing-plants in northern Ohio. A good supply of water is needed. Two small sloping-end tanks for slaking lime should be set on an elevated platform high enough so that the lime will run into the mixing tank. The mixing tank should be large enough to hold almost a sprayer-tank full. The tank for copper sulphate or blue vitriol solution should be on the same platform and preferably at the same height as the lime tanks. It should be of known capacity, so that a stock solution may be readily made up. All supply tanks should be higher than the top of the sprayer tank in order to run the mixtures into it readily. The platform around the tanks should be large so that the workmen can work on at least two sides of the tank. Only the side next to the sprayer need be left off, as long lengths of hose, pipe, etc., are not then needed to reach the sprayer. Valves or cut-offs can be omitted if sections of large-diameter hose are used, and when not in use the open end of the hose may be hooked up a little higher than the top of the supply-tank. This does away with the trouble of cut-offs clogging and being eaten out by the Bordeaux, an almost certain sequence, unless they are made of brass.

When a fruit grower intends to do much spraying he should always build a mixing-plant in order to facilitate the work. The saving of time and extra labor will pay for the mixing plant in a few seasons.

ACCESSORIES

Accessories to be considered when purchasing a spray pump:

High-pressure hose.
Long hose-couplings.
Hose-bands.
Bamboo extension-rods (brass or aluminum lined) or pipe extension rods.
Cut-offs (between rods and hose) preferably of the box type.
Three-way cut-offs.
Suction hose.
Pressure gauge.
Nozzles.
Drip guards.
Y's and angle-elbows for nozzles.
Strainers.
Hose-reducers.
A mixing plant.
Escape valve.

COST OF SPRAYING

The cost of labor for a single spraying, basing the price at $1.50 per day for a man, 75 cents for a boy, and $1.50 per day for a team. is given in a table following this paragraph. Higher wages will increase the cost proportionately. The cost per tree varies with the capacity of the machine, the size of the trees, convenience of mixing

plant and distance from orchard to filling station. As much time must be allowed for filling as for spraying out a tankful of solution, and often one must add twice as much time for filling and mixing as for emptying. These estimates are for labor only, and do not include the cost of spraying materials. For details concerning materials and methods of application see Bulletins 191 and 199 and Circular 95.

LARGE POWER OUTFITS

Capacity, 1200 to 1600 gallons per day.
Rated capacity, 7 to 11 gallons per minute at 200 pounds pressure.
Number of trees sprayed per day, 100 to 200, according to the size of the trees.
Three men and one team needed.
Actual cost of labor, 1 cent per minute for a 10-hour day.
Time used, 2 to 6 minutes per tree.
Cost per tree, 2 to 6 cents.

SMALL POWER OUTFITS

Capacity, 800 to 1100 gallons per day.
Rated capacity, 4 to 7 gallons per minute at 150 to 175 pounds pressure.
Number of trees sprayed, 60 to 120 per day.
Two men, one boy, one team.
Actual cost of labor, .875 cents per minute.
Average time per tree, 5 to 12 minutes.
Cost per tree, 4 to 11 cents.

LARGE HAND SPRAY PUMPS

Capacity, 600 to 800 gallons per day.
Rated capacity, 3 to 5 gallons per minute at 125 pounds pressure.
Number of trees sprayed, 40 to 80 per day.
Three men, one team.
Actual cost of labor, 1 cent per minute.
Average time per tree, 6 to 15 minutes.
Cost, 6 to 15 cents per tree.

LARGE BARREL PUMPS

Capacity, 400 to 700 gallons per day.
Rated capacity, 2 1-2 to 4 gallons per minute at 125 pounds pressure.
Number of trees sprayed, 25 to 50 per day.
Three men, one horse.
Actual cost of labor, .875 cents per minute.
Average time per tree, 10 to 20 minutes.
Cost per tree, 8 to 18 cents.

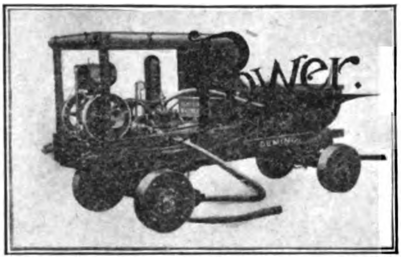
MEDIUM BARREL PUMPS

Capacity, 300 to 500 gallons per day.
Rated capacity, 1 1-2 to 2 1-2 gallons per minute at 125 pounds pressure.
Number of trees per day, 18 to 30.
Two men, one horse.
Actual cost of labor, .625 cents per minute.
Average time per tree, 18 to 36 minutes.
Cost per tree, 12 to 22 cents.

SMALL BARREL PUMPS

Capacity, 150 to 200 gallons per day.
Rated capacity, 1 to 1 3-4 gallons per minute at 125 pounds pressure.
Number of trees per day, 10 to 20.
Two men, one horse.
Actual cost of labor, .625 cents per minute.
Time per tree, 25 to 45 minutes.
Cost, 14 to 28 cents per tree.

SPRAYING OUTFITS



SPRAYING outfits are briefly described in the following list:

American Sprayer Co. An orchard traction outfit of large capacity. Peerless outfit, two models of nearly same weight. Sliding agitator, Wallace water cooled engine, 2 to 3 H.P. and double acting pump with swing check valves and a patent pressure regulator. Large air chamber, half round-bottom tank, fairly short-coupled trucks.

Invincible outfit, air cooled engine and Wallace Invincible pump. Other details similar to Peerless outfit.

Bean Spray Pump Co. The Challenge. A low, strong outfit of medium weight and large capacity, large porcelain lined cylinder, single acting pump with large bronze-ball valves. A type of propellor agitator, large air-chamber, water-cooled engine, 2 1-2 H.P. Short-coupled trucks, rectangular tank.

Deming Co. Premier outfit, large, very heavy and strong, of large capacity. New Way air-cooled engine, 2 1-2 or 3 1-2 H.P., sliding agitator, fairly long-coupled trucks, large air-chamber and double-acting pump with large ball valves. Half-round bottom tank.

Deming power outfit. Smaller and lighter than the Premier outfit but of large capacity. 1 1-2 H.P. water-cooled engine, pump, tank and trucks similar to the Premier outfit.

Cushman Power Sprayer Co. Three models, light outfits, medium and large capacity, Cushman water-cooled two cycle engine, 3 H.P. Duplex or triplex pumps, bronze ball valves, propellor agitator, round steel tanks, large wheeled, short coupled, strong trucks.

Olds Gas Power Co. Same as Deyo in most respects.

Goulds Mfg. Co. Like a Deyo outfit or a New Way outfit. Air-cooled engine 2 1-2 and 3 to 3 1-2 H.P. Goulds Vice Admiral pump, large air-chamber, wing-guided bevel-face poppet valves, sliding agitator, fairly short-coupled trucks, low and strong, half-round bottom tank.

Hardie Mfg. Co. Hardie Triplex, Light outfit, large capacity. Ideal water-cooled engine, 3 H.P., belted to Triplex pump. Ball-valves in pump, large air-chamber, half-round bottom tank, short-coupled trucks, sliding agitator.

Simplex outfit. Large and medium capacity, two sizes. Ideal water-cooled engine, 1 1-2 or 3 H.P., Simplex twin-cylinder pumps, similar to Triplex in other details.

Hardie No. 2. A light outfit, medium capacity. Ideal engine, 1 1-2 H.P., belted to pump-jack. Hardie pump, double-acting. It is without trucks and has a paddle agitator.

R. H. Deyo & Co. Deyo outfit. Heavy outfit of large capacity. Olds air-cooled engine, 2 1-2 to 3 H.P., Goulds Vice Admiral pump with large air-chamber, wing-guided bevel-faced poppet valves, sliding agitator, half-round bottom tank, fairly short-coupled trucks.

Fairbanks Morse Co. Very heavy outfit, large capacity, water-cooled engine.

Field Force Pump Co. Leader outfit, a heavy machine, large capacity, water-cooled engine, 3 1-2 H.P., sliding agitator, medium sized air-chamber, low, short-coupled trucks. Wheels with very broad tires. Half-round bottom tank.

Friend Mfg. Co. Friend regular model. Light outfit, large capacity. Friend air- or water-cooled engine, 2 1-2 to 3 1-2 H.P. New Friend pump, medium sized air-chamber, large ball-valves, half-round bottom tank, short-coupled trucks, large wheels with broad tires. Propellor agitator.

Friend Hilly Orchard. Similar excepting trucks, which have very large wheels in rear, with tank between them and small wheels in front which cut under and make an outfit which can be turned in a small area.

Spramotor Co. Light outfit. large capacity. Duplex pump, water-cooled engine, 1 1-2 H.P. Ideal engine, 2 1-2 H.P. or air-cooled engine. Sliding agitator, half-round bottom tank. Outfit has recently been revised and may be changed somewhat from the one described.

International Harvester Co. A heavy outfit of large capacity, with water-cooled engine and a double-acting pump.

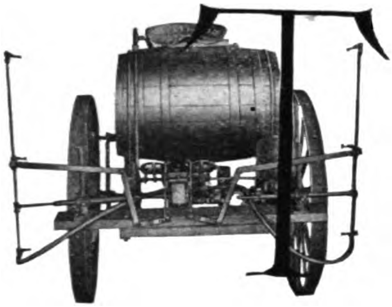
A lighter outfit of medium weight with an air-cooled engine, a double-acting pump, and a sliding agitator.

New Way Motor Co. A heavy outfit of large capacity. New Way air-cooled engine, Goulds, Deming or Myers double-acting pump. Half-round bottom tank, sliding agitator.

Binks Spraying Machine Co. Power outfit, medium weight. Water-cooled engine, double-acting pump. Sliding agitator, half-round bottom tank.

Power outfits should be chosen according to capacity and simplicity. Weight is a factor to be determined by the orchardist. His orchard may be hilly or level, and the size of trees and the kind of usage a machine is to get will determine what sort of an outfit to purchase. Extremely light outfits, in most cases, are not as durable as the slightly heavier types. Weight and strength have been sacrificed for lightness, but the durability of such an outfit is in some few makes of machines nearly equal that of the heaviest types. Type of pump, valves, etc., also figure largely in durability, but most of the leading pump manufacturers use bronze-ball or bevel-faced wing-guided poppet valves, so this factor does not enter so largely in the choice of a pump. *Capacity*, *simplicity*, *efficiency*, *durability* and *cost*, are the factors one must consider. Choose preferably a close-coupled truck, with fairly large wheels in the rear and smaller wheels in front, all wheels with broad tires, and with the spraying machine frame set low, using the wagon without a bolster in the rear, if possible, but with the machine set level.

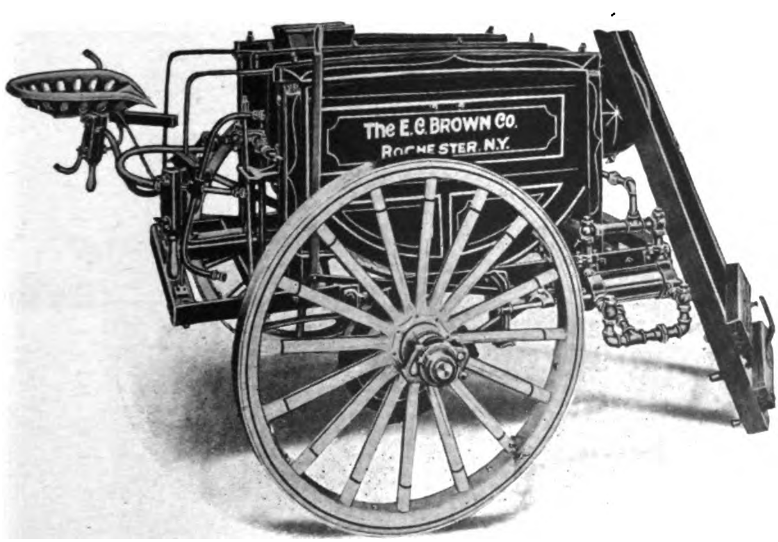
Home-made power outfits are not advisable, as very few have the facilities for connecting up pump and engine satisfactorily. Special purpose machines may be built at home, and also a good hand or independent power pump outfit may be readily assembled.



TRACTION-POWER sprayers are for the most part, special purpose machines. There are a few machines of this type built for orchard spraying but most of them were designed for spraying grapes, potatoes and similar field crops, or spraying for the destruction of weeds. Power is transmitted from the wheels by means of cams, eccentrics, chains or gears, and the pump is operated by these various mechanical contrivances. Here, as in the case of other types, the same factors, *strength*, *simplicity*, *durability* and *capacity*, must be considered.

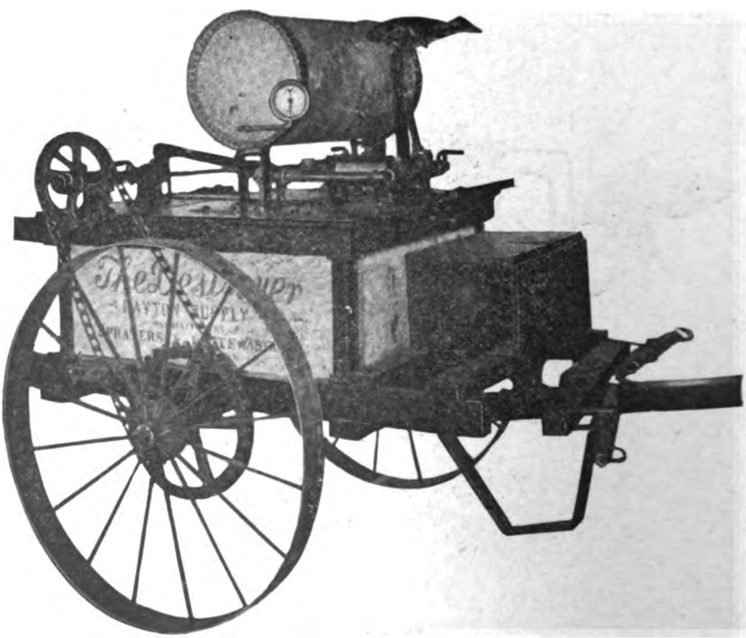
Traction machines were designed as special purpose machines, and are not a complete success for orchard spraying. Some few machines can be operated as hand pumps as well as used as traction machines.

For the man who has a small orchard and needs a field sprayer, some machine of this type should be selected; but the fruit grower who has a large orchard must look to the other types for a more suitable machine.

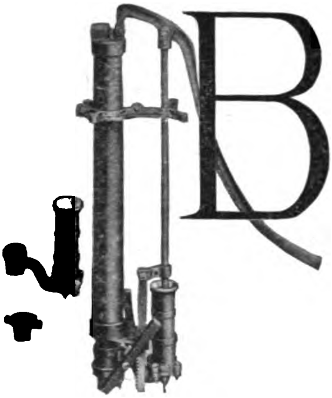


A traction sprayer with double-acting pump operated by an eccentric.

LARGE hand pumps approach small power machines in capacity and are better than any barrel pumps on account of the long leverage that can be used. Two cylinders of smaller diameter are often used and the capacity is then greatly increased over that of the ordinary barrel pump. The entire weight of the body can be applied to the lever without stooping or bending the back, while any type of a tank or barrel can be used as the spray liquid container. For the man who cannot afford a power sprayer, or who has a medium sized orchard and can get cheap labor, this style is very satisfactory.



A traction sprayer with a double-acting chain driven pump.

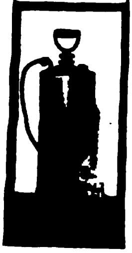


BARREL pumps of medium capacity are well suited to the small fruit grower or farmer who does not care to invest much money and yet wishes to raise good fruit. Medium capacity barrel pumps are to be preferred before the large capacity barrel pumps because the latter are hard to operate and it takes a heavy, strong man to pump one all day. Besides being useful for the man with a small home orchard, they may be successfully used for cold water painting, whitewashing, spraying chicken coops to destroy mites, lice, etc.

A barrel pump with valves, plunger and packing readily accessible.

BUCKET pumps were never designed for spraying the apple orchard, but they are convenient for spraying truck crops, small trees and bushes around the yard, chicken coops, and doing many other small jobs about the home, where a small convenient pump is needed. The Knapsack pump is a portable type of bucket pump, very useful for small work, and for spraying truck and garden crops.

A barrel pump with plumbing connections and parts not readily accessible.



AUTOMATIC sprayers are more convenient than knapsack sprayers, for they may be filled and then pumped up with air and the entire attention of the operator can be devoted to spraying without having to do the double duty of pumping and spraying at the same time. They are very convenient and readily carried about. For truck crops they are hard to beat when they are *well made.*

A fault of the larger part of the sprayers of this type is that they are made of galvanized iron and are corroded so rapidly by the Bordeaux sprays that they become worthless in a year or two. To be durable they must be constructed of heavy sheet brass, preferably seamless or with well riveted joints. For small work, a well made sprayer of this type is almost ideal.

COMPRESSED air sprayers have some advantages, since they are easily operated and are of very simple construction. For such outfits the first cost of the charging and mixing plant and of the sprayer tanks is somewhat greater than that of the average power outfit having an equivalent daily capacity, so far as the amount of liquid sprayed out is concerned. The pressure, when using a compressed air sprayer, must vary between two extremes, usually from 160 to 80 pounds while the tankful of solution is being discharged. This tends to make the work uneven, since the quality of the spray varies from fine to coarse and there is also a variation in the amount of liquid discharged in a given time. On the other hand, power outfits are operated under an almost constant pressure which is often as great as 200 pounds to the square inch.

Considering these facts, and also that the amount of skilled labor required to operate either outfit is practically the same, I have reached the conclusion, after having operated both types of outfits in the field, that for the average orchardist, a power outfit is superior to the compressed air outfit.

In either case the operator must possess average mechanical ability and exercise reasonable care.

Sprayers using compressed gas have the disadvantage of decomposing the lime-sulfur sprays. For killing scale insects, lime-sulfur spray is one of the best, and is almost universally used in orchard work.

Dust sprayers have been successfully used in treating cotton, tobacco and a few similar field crops. In general orchard work they have not proved a success, as has been demonstrated in extensive competitive tests against liquid sprayers. However they have shown merit for such special use as dusting orange groves for rust mite. Their range of usefulness is evidently quite restricted.

In the following tables I have attempted to list the manufacturers who make various kinds of machines, so that an intending purchaser may write to those companies which build the kind of a machine he wishes to purchase, for catalogues and prices of the same.

Companies making Independent pumps to which power can be adapted:

American Sprayer Co., Minneapolis, Minn.
Bean Spray Pump Co., Cleveland, Ohio.
The Deming Co., Salem, Ohio.
Field Force Pump Co., Elmira, N. Y.
Goulds Mfg. Co., Seneca Falls, N. Y.
Hardie Mfg. Co., Hudson, Mich.
F. E. Myers & Bro., Ashland, Ohio.
Spramotor Co., Buffalo, N. Y.

Companies manufacturing traction machines for grape, potato and field spraying, but sometimes adapted for use in orchards:

American Sprayer Co., Minneapolis, Minn.
E. C. Brown Co., Rochester, N. Y.
Dayton Supply Co., Dayton, Ohio.
Field Force Pump Co., Elmira, N. Y.
Goulds Mfg. Co., Seneca Falls, N. Y.
Hardie Mfg. Co., Hudson, Mich.
H. L. Hurst Mfg. Co., Canton, Ohio.
Latham & Co., Sandusky, Ohio.
Spramotor Co., Buffalo, N. Y.
Wm. Stahl Sprayer Co., Quincy, Ill.

Companies manufacturing large capacity hand pumps:

Bean Spray Pump Co., Cleveland, Ohio.
E. C. Brown Co., Rochester, N. Y.
The Deming Co., Salem, Ohio.
Field Force Pump Co., Elmira, N. Y.
Friend Mfg. Co., Gasport. N. Y.
Goulds Mfg. Co., Seneca Falls. N. Y.
Hardie Mfg. Co., Hudson, Mich.
F. E. Myers & Bro., Ashland, Ohio.
Spramotor Co., Buffalo, N. Y.
Wm. Stahl Sprayer Co., Quincy, Ill.

Companies manufacturing large capacity barrel pumps, the rated capacity of which is over two and one-half gallons per minute:

American Sprayer Co., Minneapolis, Minn.
Field Force Pump Co., Elmira, N. Y.
Goulds Mfg. Co., Seneca Falls, N. Y.
Hardie Mfg. Co., Hudson, Mich.
Latham & Co., Sandusky, Ohio.
Morrill & Morley, Benton Harbor, Mich.
Spramotor Co., Buffalo, N. Y.
Wm. Stahl Sprayer Co., Quincy, Ill.

Companies manufacturing medium and small capacity barrel pumps.

American Sprayer Co., Minneapolis, Minn.
Barnes Mfg. Co., Mansfield, Ohio.
Bean Spray Pump Co., Cleveland, Ohio.
E. C. Brown Co., Rochester, N. Y.
Dayton Supply Co., Dayton, Ohio.
Deming Co., Salem, Ohio..
Field Force Pump Co., Elmira, N. Y.
Friend Mfg. Co., Gasport, Ohio.
Goulds Mfg. Co., Seneca Falls, N. Y.
Hardie Mfg. Co., Hudson, Mich.
H. L. Hurst Mfg. Co., Canton, Ohio.
Latham & Co., Sandusky, Ohio.
F. E, Myers & Bro., Ashland. Ohio.
Spramotor Co., Buffalo, N. Y.
Wm. Stahl Sprayer Co., Quincy, Ill.

Companies manufacturing Kerowater or Kerosene mixing sprayers:

Dayton Supply Co., Dayton, Ohio.
Deming Co., Salem, Ohio.
Goulds Mfg. Co., Seneca Falls, N. Y.
Spramotor Co., Buffalo, N. Y.

Companies manufacturing Knapsack sprayers:

Barnes Mfg. Co., Mansfield, Ohio.
Deming Co., Salem, Ohio.
Field Force Pump Co., Elmira, N. Y.
Goulds Mfg. Co., Seneca Falls, N. Y.
F. E. Myers & Bro., Ashland, Ohio.
Spramotor Co., Buffalo, N. Y.
Wm. Stahl Sprayer Co., Quincy, Ill.

Companies manufacturing bucket pumps:

American Sprayer Co., Minneapolis, Minn.
Barnes Mfg. Co., Mansfield, Ohio.
Bean Spray Pump Co., Cleveland, Ohio.
E. C. Brown Co., Rochester, N. Y.
Dayton Supply Co., Dayton, Ohio.
Deming Co., Salem, Ohio.
Field Force Pump Co., Elmira, N. Y.
Goulds Mfg. Co., Seneca Falls, N. Y.
Hardie Mfg. Co., Hudson, Mich.
H. L. Hurst Mfg. Co., Canton, Ohio.
F. E. Myers & Bro., Ashland, Ohio.
Wm. Stahl Sprayer Co., Quincy, Ill.

Companies manufacturing automatic sprayers:
- American Sprayer Co., Minneapolis, Minn.
- Bean Spray Pump Co., Cleveland Ohio.
- E. C. Brown Co., Rochester, N. Y.
- Dayton Supply Co., Dayton, Ohio.
- Field Force Pump Co., Elmira, N. Y.
- Hardie Mfg. Co., Hudson, Mich.
- H. L. Hurst Mfg. Co., Canton, Ohio.

Companies manufacturing compressed air sprayers:
- American Horticultural Distributing Co., Martinsburg, W. Va.
- Latham & Co., Sandusky, Ohio.
- Niagara Sprayer Co., Middleport, N. Y.
- Pierce-Loop Co., Northeast, Pa.

Companies mancfacturing dust sprayers:
- Dust Sprayer Co., Kansas City, Mo.
- Leggett & Bros., New York, N. Y.

Companies assembling or manufacturing spraying machines:
- American Sprayer Co., Minneapolis, Minn.
- Barnes Mfg. Co., Mansfield, Ohio.
- Bean Spray Pump Co., Cleveland, Ohio.
- Binks Spraying Machinery Co., Chicago, Ill.
- Cushman Power Sprayer Co., Lincoln, Neb.
- E. C. Brown Co., Rochester, N. Y.
- Dayton Supply Co., Dayton, Ohio.
- Deming Co., Salem Ohio.
- R. H. Deyo & Co., Binghamton, N. Y.
- W. & B. Douglas, Middleton, Pa.
- Fairbanks, Morse & Co., Cleveland, Ohio.
- Field Force Pump Co., Elmira, N. Y.
- Friend Mfg. Co.; Gasport, N. Y.
- Gilson Mfg. Co., Port Washington, Wis.
- The Goulds Mfg. Co., Seneca Falls, N. Y.
- The Hardie Mfg. Co., Hudson, Mich.
- Hurst Mfg. Co., Canton, Ohio.
- International Harvester Co., Local agencies.
- Latham & Co., Sandusky, Ohio.
- Morrill & Morley, Benton Harbor, Mich.
- F. E. Myers & Bro.. Ashland, Ohio.
- The New Way Motor Co., Lansing, Mich.
- Niagara Spraying Co., Middleport, N. Y.
- Olds Gas Power Co., Lansing, Mich.

Pierce-Loop Co., Northeast, Pa.
Spramotor Co., Buffalo, N. Y.
Wm. Stahl Sprayer Co., Quincy, Ill.

In the following tables machines manufactured by the various companies are listed. The first column gives the name of the pump, the second, the kind of pump, the third, the capacity of the pump per minute, as the companies approved of or sent as correct at the pressure indicated in the fourth column, and the speeds given in the sixth column. The fifth column gives the estimates at the same speed and pressures as the companies capacities were given, but using the actual amount of liquid displaced per minute by the plunger. This does not allow for leaky valves, plunger-packing or jet agitators, so it is a little high in every case. Column seven gives the type of valves used in the pump; columns eight and nine, the length of stroke and diameter of the cylinders; column ten, the additional remarks upon the various types of pumps.

AMERICAN SPRAYER COMPANY

Name	Kind of machine	Companies capacities Gallons	Pressure Lbs.	Estimated capacities Gals.	Speed in strokes per minute	Type of valves	Length of stroke Ins.	Diameter of cylind'r Ins.	Remarks
Peerless	Power	8 to 11	200	8 to 12	50 strokes	Swing check	4	3	Double acting, rod clamped, brass cylinder with stuffing box.
Invincible	Indpt. power	7 to 9	200	7 to 9	"	"	3	3	
Standard	Traction	20	125	18	250 feet per	"	8	3	" "
Wallace Jr.	"	14	125	12	"	"	3	3	" "
Wallace Field	"	15 1-2	125	13	"	"	4	4	" "
Wallace Potato	"	10	125	9	"	"	3	3	" "
Wallace Grape	"	10	125	9	"	"	3	3	" "
Eureka No. 4	Barrel	1 to 1 1-4	125	1 to 1 3-4	30 strokes	"	4, 4 1-2	2	Single acting, brass cylinder, inside plunger packed.
Eureka No. 5	"	2 to 2 1-2	125	2 to 2 1-2	"	"	4 1-2, 5	2 1-2	
Eureka No. 6	"	3 to 4	125	3 to 4	"	"	4 1-2, 5	2 3-4	" "

BARNES MANUFACTURING COMPANY

Name	Kind of machine	Companies capacities Gallons	Pressure Lbs.	Estimated capacities Gals.	Speed in strokes per minute	Type of valves	Length of stroke Ins.	Diameter of cylind'r Ins.	Remarks
Perfection	Bucket	1 1-2	50	1	30 strokes	Rubber ball	17	1	
Double Acting	Barrel	1 1-2 to 2	125	1 1-2 to 2	"	Poppet	3 1-4	2 1-2	A double acting pump with brass cylinder and with a small reversed brass cylinder and plunger above doing away with a stuffing box
New Improved	"	2 to 2 1-2	125	2 to 2 1-2	"	"	4	2 1-2	
Perfection	Bucket-barrel	1 to 1 1-4	125	1 to 1 1-4	"	Rubber ball	5 1-2	1 1-4	
Fig. 256		2 per	125	2 per	"	Bronze "	12	1 1-4	

BEAN SPRAY PUMP COMPANY

Name	Kind of machine	Companies capacities Gallons	Pressure Lbs.	Estimated capacities Gals.	Speed in strokes per minute	Type of valves	Length of stroke Ins.	Diameter of cylind'r Ins.	Remarks
Challenge	Power	6 to 7	200	6 to 8	50 strokes	Bronze ball	4	3	Single acting, porcelain lined cylinder, packing is a rubber composition cup.
Power	Indpt. power	10 to 11	200	10 to 12	"	"	4	3	
Torrent	Hand	5 to 5 1-2	125	5 to 5 1-2	30 strokes	"	4	2 1-2	
Magic No. 9	"	3 to 4	125	3 to 4	"	"	4 1-2	3	
Magic No. 10	"	2 to 3	125	2 to 3	"	"	4 1-2	2 1-2	
Nos. 7 and 6	"		125		"	"			
Junior No. 1	"	2 to 3	125	2 to 3	"	"	4	2 1-2	
No. 70	Barrel	1 1-2 to 2	125	1 1-2 to 2	"	"	3 1-2	2 1-4	
No. 60	"	1 1-2 to 2	125	1 1-2 to 2	"	"	3 1-2	2 1-4	

E. C. BROWN COMPANY

Name	Kind	Companies capacity Gallons	Pressure Lbs.	Estimated capacities Gallons	Speed in strokes per minute	Type of valves	Length of stroke Ins.	Diameter of cylind'r Ins.	Remarks
Auto Spray No. 24	Barrel	1 1-2 to 2	125	1 1-2 to 2	30 strokes	Steam	4	2 1-4	Outside packing, single action pump, plunger of hollow tube type, two cylinders, single acting, with packing on outside of plunger.
" " 7	Hand	4 to 6	125	4 to 6	"	check	5	2 1-4	
" " 11	Traction	5 to 6	125	5 to 6	Calculated	valves in	6	2 1-2	All double acting stuffing box types of cylinders with cylinder tubes held in place by rods clamping on the cylinder heads.
" " 15	"	5 to 6	125	5 to 6	that horse	all but	6	2 1-2	
" " 23	"	10 to 11	125	10 to 11	travels at	AutoSpray	6	2 1-2	
" " 27	"	5 to 6	125	5 to 6	250 feet per	30 and No.	6	2 1-2	
" " 28	"	10 to 11	125	10 to 11	minute	2 Bucket,	6	2 1-2	
" " 29	"	10 to 11	125	10 to 11	under	which have	6	2 1-2	
" " 31	"	10 to 11	125	10 to 11	ordinary	ball valves.	6	2 1-2	
" " 32	"	5 to 6	125	5 to 6	conditions.		6	2 1-2	
" " 33	"	10 to 11	125	10 to 11			6	2 1-2	

DAYTON SUPPLY COMPANY

Name	Kind	Companies capacity Gallons	Pressure Lbs.	Estimated capacities Gallons	Speed in strokes per minute	Type of valves	Length of stroke Ins.	Diameter of cylind'r Ins.	Remarks
Climax No. 1	Barrel	.9	125	.9	30 strokes	Poppet	5	1 1-4	Stuffing box, single acting valve in plunger types like well pumps
" " 2	"	1.6	125	1.6	"	"	5	1 1-2	
" " 3	"	2 to 2 1-4	125	2 to 2 1-4	"	"	5	2	
Destroyer	Traction	6 to 8	125	6 to 8	250 feet per	P & B check	5	2 1-2	Double acting stuffing box, rod clamped cylinder types.
Dolphin	"	3 to 4	125	3 to 4	minute for	"	5	1	
Orchard	"		125		traction	"			
Economy	Bucket	1	125	1	types				

THE DEMING COMPANY

Name	Kind	Companies capacity Gallons	Pressure Lbs.	Estimated capacities Gallons	Speed in strokes per minute	Type of valves	Length of stroke Ins.	Diameter of cylind'r Ins.	Remarks
Premier	Power	7 to 10	200	8 to 9	50 strokes	Bronze ball	4	2 1-2	Stuffing box double acting type, with brass cylinder inside of cast iron frame. The Premier power and Independent power are built with crossheads and guides. Canvas cups or rubber composition cups used on plungers.
Power	"	7 to 9	150	6 to 8	"	"	4 1-2	2 1-2	
Bonanza Power	"	4 to 5	200	4 to 5	"	"	3 1-2	2	
" "	"	8 to 9	200	8 to 9	"	"	4 1-2	2 1-2	
Indpt. Power	Indpt. power	7 to 10	200	8 to 9	"	"	4 1-2	2 1-2	
Sampson	Hand	3 to 5	125	3 to 5	30 strokes	"	3	2 1-2	No stuffing box, small reversed plunger above.
Bonanza 1	"	2 to 3	125	2 to 3	"	"	3 1-2	2	Similar to power pumps in construction.
" 2	"	4 to 5 1-2	125	4 to 5 1-2	"	"	4 1-2	2 1-2	"
Century 1	Barrel	1 1-2 to 2	125	1 1-2 to 2	"	"	4 1-2	1 3-4	Single acting pumps without a stuffing box.
" 2	"	2 to 2 1-2	125	2 to 2 1-2	"	"	4 1-2	2 1-4	" "
Granger	"	1 1-2 to 2	125	1 1-2 to 2	"	"	4 1-2	1 3-4	Single acting, inside plunger packing.
Simplex	"	2 to 2 1-2	125	2 to 2 1-2	"	"	4 1-2	2 1-4	Single acting, stuffing box type.
Captain	"	1 1-2 to 2	125	1 1-2 to 2	"	"	4 1-2	1 3-4	Single acting, inside plunger packing.
Gem Jr	"	3-4 to 1	125	3-4 to 1	"	"	4	1 1-2	Single acting, stuffing box type.
Bucket	Bucket	3-4 to 1	125	3-4 to 1	"	"	15	1	

FIFLD FORCE PUMP COMPANY

Name	Kind	Companies capacities Gallons	Pressure Lbs.	Estimated capacities Gallons	Speed in strokes per minute	Type of valves	Length of stroke Ins.	Diameter of cylind'r Ins.	Remarks
Leader	Power	7 to 10	200	7 to 10	50 strokes	Poppet	5	2 1-2	Double acting pumps with stuffing box.
"	"	8 to 12	200	9 to 12	"	"	5	3	" " "
Ideal	Indpt. Power	12	200	9 per	"	"	4	2 1-2	" " "
Admiral	Hand	10 to 11	125	5 to 7	30 strokes	"	5	2 1-2	" " "
Empire Queen	Barrel	2 to 3	125	1 1-4 to 2	"	"	3 to 4	2	Single acting pump with a stuffing box.
Empire King	"	3 to 6	125	2 1-2 to 3 1-4	"	"	3 to 4	2 1-2	" " "
Jr. Empire King	"	2 1-2 to 5 1-2	125	2 to 3	"	"	3 to 4	2 1-2	" " "
Niagara Hydraulic	Hand	3 to 6	125	2 to 3 1-4	"	"	4	2 1-2	" " "
Victor	Traction	10 to 12	125	6 to 9	250 feet per	"	3	2, 3	" " "
Wooster	"	5 to 8	125	4 to 5	"	"	3	1, 3	" " "
Watson	"	6 to 10	125	5 to 6	"	"	3	2 1-2	" " "
Wild Rose	"	10 to 12	125	6 to 9	"	"	3	3	" " "
Aroostook	"	10 to 12	125	6 to 9	"	"	3	3	" " "
Eagle	Barrel	3 to 6	125	2 to 3 1-4	30 strokes	"	4	2 1-2	Single acting pump without a stuffing box.

FRIEND MANUFACTURING COMPANY

Name	Kind	Companies capacities Gallons	Pressure Lbs.	Estimated capacities Gallons	Speed in strokes per minute	Type of valves	Length of stroke Ins.	Diameter of cylind'r Ins.	Remarks
Friend	Power	7 to 8	200	7 to 8	50 strokes	Ball	3 1-2	2	Cylinder, outside plunger packed, single acting.
Friend Jr	Barrel	2	125	2	30 strokes	"			

GOULDS MANUFACTURING COMPANY

Name	Kind	Companies capacities Gallons	Pressure Lbs.	Estimated capacities Gallons	Speed in strokes per minute	Type of valves	Length of stroke Ins.	Diameter of cylind'r Ins.	Remarks
Triplex	Power	8 to 10	200	8 to 10	50 strokes	Bevel-faced	3 1-2		
Vice Admiral	"	7 to 8	200	7 to 8	"	wing-	4 1-2	2 1-2	The Admirals are double acting pumps, brass
" "	"	8 to 10	200	8 to 10	"	guided	4 1-2	3	lined cylinders, with a stuffing box.
Emperor	"	6 to 8	200	6 to 8	"	poppet	4	2 1-2	Emperor and Monarch have single acting double
"	"	4 to 6	200	4 to 6	"	valves.	4	2	cylinders with outside plunger packing.
Monarch	Hand	4 to 5	125	4 to 5	30 strokes		4	2 1-2	
"	"	3	125	3	"		4	2	
Pomona	Barrel	2 to 3 1-4	125	2 to 3 1-4	"		3, 4 or 5	2 1-2	Barrel pumps are single acting and all are
Savelot	"	2 to 3 1-4	125	2 1-2 to 3 1-4	"		3, 4 or 5	2 1-2	without stuffing boxes.
Fruitall	"	1 1-2 to 1 2-3	125	1 1-2 to 1 2-3	"		4	2	
Standard	"	2 1-4 to 3 1-4	125	2 to 2 1-2	"		3 1-2	2 1-2	
Premier	Bucket	1	125	1	"				
Admiral	Hand	5	125	5	"		4 1-2	2 1-2	
"	"	7	125	7	"		4 1-2	3	
Standard	Barrel	2 1-2 to 3 1-4		2 1-2 to 3 1-4	"		3 1-2	3	

HARDIE MANUFACTURING COMPANY

Name	Kind	Companies capacities Gallons	Pressure Ins.	Estimated capacities Gallons	Speed in strokes per minute	Type of valve	Length of stroke Ins.	Diameter of cylind'r Ins.	Remarks
Triplex	Power	5 to 8	200	5 to 7	50 to 80	Bronze ball	2 3-4	2	All power machines excepting No. 2 have outside plunger packing, single acting cylinder types.
Simplex C	"	7	200	7	50 strokes	"	3 1-2	2 1-2	
Simplex D	"	5 1-2	200	4 1-2	"	"	3 1-2	2	No. 2 double acting pump with cylinder threaded to receive the cylinder heads.
No. 2	"	4 to 5	175	4 to 5	"	"	5	1 5-8	
Twin cylinder	Hand	3 to 3 1-2	125	3 to 3 1-2	30 strokes	"	3 1-2	2	Outside plunger packing, 2 single cylinders.
No. 4½	Barrel	2-3	125	2-3	"	"	3 1-2	1 5-8	Inside plunger packed, single acting pumps without a stuffing box.
No. 5	"	1 1-3	125	1 1-3	"	"	4	1 6-8	
No. 6	"	2	125	2	"	"	5	2	
No. 7	"	4	125	4	"	"	5	2 1-2	" "
Bucket	Bucket	1-2	125	2-3	"	"	5	1 1-4	

H. L. HURST MANUFACTURING COMPANY

Name	Kind	Companies capacities Gallons	Pressure Ins.	Estimated capacities Gallons	Speed in strokes per minute	Type of valve	Length of stroke Ins.	Diameter of cylind'r Ins.	Remarks
Fitzall	Barrel	1 1-2 to 1 3-4	125	1 1-2 to 1 3-4	30 strokes	Bronze ball	4 1-2	2 1-4	Single acting outside plunger, packed pumps.
Hurst	Traction	4 to 5	125	4 to 5	250 feet per	"	4	2 1-2	

LATHAM & COMPANY

Name	Kind	Companies capacities Gallons	Pressure Ins.	Estimated capacities Gallons	Speed in strokes per minute	Type of valve	Length of stroke Ins.	Diameter of cylind'r Ins.	Remarks
Latham 3	Barrel	1 to 1 1-2	125	1 1-2 to 2	30 strokes	Poppet	3 to 5	2	Single acting without a stuffing box.
" 4	"	2 to 2 1-2	125	2 to 3 1-4	"	"	3 to 5	2 1-2	A unique type.

MORRILL & MORLEY

Name	Kind	Companies capacities Gallons	Pressure Ins.	Estimated capacities Gallons	Speed in strokes per minute	Type of valve	Length of stroke Ins.	Diameter of cylind'r Ins.	Remarks
Barrel	Barrel	2 to 3	125	2 to 3	30 strokes	Poppet	3 to 4	3	Single acting, inside packed plunger.

F. E. MYERS & BROTHER

Name	Kind	Companies capacity Gallons	Pressure Lbs.	Estimated capacity Gallons	Speed in strokes per minute	Type of valves	Length of stroke Ins.	Diameter of cylind'r Ins.	Remarks
Pitman Power	Power	7 to 10	200	7 to 10	50 strokes	Poppet	5	2 1-2	Double acting pump with stuffing box and brass lined cylinder.
" "	"	5 to 7	200	5 to 7	"	"	5	2	
Back Geared	"	6	200	6	"	"			
Hydraulic	Hand	3 1-4	125	3 1-4	30 strokes	"	4 1-2	2	These pumps are without a stuffing box and have a reversed plunger in the double-acting barrel pumps.
"	"	3	125	3	"	"	5	2 1-2	
Double Acting	"	5	125	5	"	"	4 1-2	2 1-2	
" "	"	3 1-4	125	3 1-4	"	"	4 1-2	2	
" " Barrel	Barrel	2	125	2	"	"	3 1-2	2 1-2	
O.K.		2	125	2	"	"	3 1-2	2 1-2	
Perfect	Barrel	2	125	2	"	Ball	3 1-2	2 1-2	
SPRAMOTOR COMPANY									
Duplex Power	Power	6 to 8	200	6 to 8	50 strokes	Ball	6	2	All inside plunger packed, single acting pumps with no stuffing box and one or two brass cylinders.
Duplex	Hand	4 to 5	125	4 to 5	30 strokes	"	6	2	
Field and Grape	Traction	5 to 8	125	5 to 8	"	"	6	2	
Sprapainter	Barrel	2 to 3	125	2 to 3	"	"	3.5 - 5.5	2 1-2	
Spramotor No. 0	"	1 to 1 3-8	125	1 to 1 3-8	"	"	4 1-2	1 3-8	
" " 1	"	3 to 4	125	3 to 4	"	"	4 to 5	3	
" " 2	"	4 to 6	125	4 to 7	"	"	4.5 - 5.5	3 1-2	
Knapsack	Knapsack	1-2	125	1-2	"	"	3 1-2	1 1-4	
Wm. STAHL SPRAYER COMPANY									
Excelsior No. 27	Hand	4	125	3 1-2 to 4	30 strokes	Poppet	2 3-4	2 1-2	Double acting stuffing box type. Similar to Gould's barrel pumps in construction
" " 22	Barrel	2 to 3	125	2 to 3	"	"	3 to 5	2 1-2	
" " 24	"	1 1-1	125	1 1-2	"	"	4	2	
" " 29	"	2 to 3	126	1 1-2 to 2	"	"	3	2 1-2	

In conclusion let me set forth a *few things which should be remembered.*

1 Choose a machine that has the factors of *simplicity*, *durability* and *capacity* and the *efficiency* of the machine will be unquestioned.

2 Cost is another question. A few dollars higher in price usually means *better quality* and "the best is the cheapest in the end."

3 *Clean* up your *machine* and *accessories each time* when you are *through spraying.*

4 *Keep* your machine in *good trim*, all *bolts* and *bearings tight*, *plunger packed*, etc.

5 Use *good* oil and *plenty* of it.

6 If something goes wrong and fails to work *find out* what the *trouble* is, before you *change any adjustments. Changing adjustments* without knowing *why* only *means more trouble.*

7 *Results* depend upon *thorough work* and the *use* of *good standard brands* of spraying materials.

8 *Study* your *machine* and your *problem* and *persevere.*

ACKNOWLEDGEMENTS

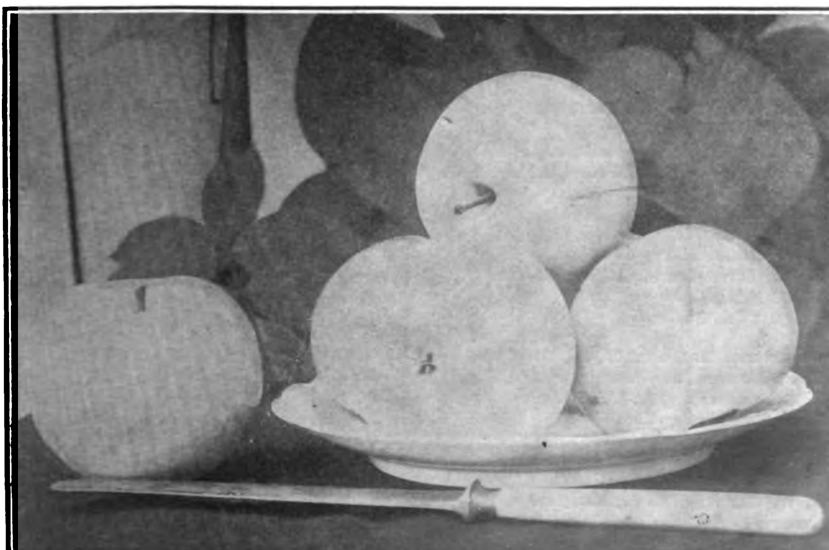
To the spraying machinery companies for their kindness and assistance in furnishing parts of machines and illustrations for the illustrated lecture which led to the preparation of this bulletin; to the Station photographer, Mr. Wm. P. Beeching Jr., who prepared the designs for the illustration of this bulletin, and to all those who assisted in other ways, I wish to express my thanks.

APPLE CULTURE IN OHIO

OHIO
Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., MAY, 1910

BULLETIN 217



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BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 218 JUNE, 1910

THE STATUS OF THE POTATO GROWING INDUSTRY IN OHIO

By F. H. BALLOU

Potato culture, in Ohio, is rapidly developing into a vast industry. The crop of 1907—the last year for which statistics are available—reached the enormous aggregate of 10,825,659 bushels. Among the staple products of Ohio soil, potatoes, therefore, rank fourth in the number of bushels produced—corn being first, oats second and wheat third.

Roughly dividing the state into four parts by drawing an imaginary line from Sandusky on the north to Ironton on the south; and from Bellaire, in Belmont county, on the east to Greenville, Darke county on the west, we find that, in the northeastern quarter were grown in 1907, approximately 5,800,000 bushels, or more than one-half of the total production of the entire state.

The ten heaviest potato producing counties of Ohio are Portage, Wayne, Medina, Cuyahoga, Hamilton, Stark, Lucas, Summit, Erie and Mahoning, named in the order of their yields for 1907, beginning with the highest. The same counties have maintained their precedence as the banner producers for the past ten years, although the order of individual yields may have been transposed occasionally—especially those noted for close competition. Seven of the ten heaviest producing counties, in 1907, were embraced wholly within the northeastern quarter; also the greater part of another—Erie. Lucas county, the seventh in point of production, and a small part of Erie, are in the northwestern quarter. Hamilton county, the fifth in point of production, in 1907, contributes this distinction to the southwestern quarter.

While these figures and data are interesting, they should by no means be construed to suggest that outside of the sections and counties named this industry is not followed with success and profit,

nor that potatoes of equally as fine quality cannot be grown. The valleys of the Great Miami, Little Miami, Scioto, Licking, Hocking, Muskingum and other rivers and their hundreds of tributaries, as well as many fertile, upland soils in various other parts of the state, yield fully as high an average per acre in bushels, and equally as good potatoes as relates to table quality.

The ten lightest potato producing counties of the state, during the period of the last ten years, are Fayette, Union, Highland, Madison, Harrison, Preble, Warren, Adams, Jackson and Gallia. Of these counties, during the period of the last ten years, Fayette stands notable as the least devoted to potato culture, therefore producing the least number of bushels, of any county in Ohio. Its average for the ten years is about 7,200 bushels per year. Only 580 bushels were grown in Fayette county in 1907. This county will illustrate the fact that the status of the potato growing industry in different counties is determined not by the degree of fertility or productivity of the soils of these counties, but by the branch or branches of agriculture or horticulture which are specialized by the land owners thereof.

In addition to the regular lines of potato work at the Experiment Station there has been considerable material of a miscellaneous nature gradually accumulating through special experiments and careful observations both at the Station grounds and throughout the state, which should be of much practical value to the potato grower, especially the beginner. The more important features of this accumulated fund of practical information are now assembled in this bulletin, inasmuch as it was considered that such a publication would clearly and fully answer many oft-recurring questions from correspondents, which cannot be fully and satisfactorily answered within the limited scope of personal letters to each one.

ROTATIONS FOR POTATOES

An excellent rotation for the potato farmer is a three-year cycle of potatoes, wheat and clover. Barnyard manure, unless it be well rotted, in this rotation is preferably used as a winter top-dressing on the wheat or clover. It is not advisable to plow under fresh stable manure in preparation for potatoes, as such manure favors conditions under which the tubers are likely to be more or less attacked by the scab fungus, thereby blemishing a portion of the crop. The aim should be to induce a strong growth of clover, and to this end lime may often be used to advantage on the wheat preceding the clover crop.

Another good rotation for the potato grower who is also engaged in strawberry growing, is clover, potatoes and strawberries. In detail, the strawberry bed is plowed under at the close of the first or second season's fruiting, the soil finely and firmly worked down and medium red clover immediately sown at the rate of 15 or 20 pounds per acre. This plan of mid-July clover seeding has rarely met with failure under the writer's observation or practice. If the season be at all favorable the clover will make a good growth the same season of sowing. A crop of hay may be taken the following season, the second growth being allowed to remain on the ground to be turned under the following spring. Potatoes follow the clover, and after these are harvested rye is sown as a winter cover crop to be turned under the succeeding spring in preparation for strawberries. This plan provides for a four-year rotation if a single crop of strawberries be gathered, or a five-year rotation if two crops be harvested. Other garden crops may be substituted for the strawberries if the grower desire. A late crop of potatoes, using sprouted seed, may also be grown after strawberries. This plan is usually very satisfactory if properly carried out, often giving a yield of potatoes equal to or greater than the early planted crop. The strawberry bed should first be thoroughly disked and then plowed and carefully harrowed, then rolled and harrowed again. Wheat and then clover follow the potatoes.

PREPARATION OF THE SOIL AND METHOD OF APPLICATION OF FERTILIZERS

The question is often submitted: "Is it a commendable plan to plow ground, intended for potatoes, in the autumn or during open periods in the winter?" Fall or winter plowing might be advisable under certain conditions. These conditions would depend principally upon the character of the soil and the amount of work to be done with a given force of help. If the soil be tenacious clay or heavy clay loam, plowing too far in advance of the planting season would certainly result in the soil becoming so compacted by late winter and early spring rains that preparation of a deep, mellow seed-bed would be a difficult proposition. Lighter clay loams abounding in humus, or soils of a sandy nature, might safely be plowed in autumn or winter, providing they are so situated that there is no great danger of loss of soil and fertility by washing, as would be the case on steep hill-slopes. In any case where fall plowing is practiced it is well to work the ground as deeply as possible in the spring with a disk harrow or two-horse cultivator. Those who farm level or comparatively level land do not realize the importance of great care in this respect in the hilly sections.

In a general way it may be stated that the better plan is to plow potato ground as early in the spring as the ground becomes in good condition to work. In sections of the state where early planting is practiced it is the custom to plow, prepare and plant at once. In other sections, as in certain parts of northern Ohio, where June planting is the rule, the ground may well be plowed as soon in the spring as it will work well and harrowed every week or ten days until the chosen time of planting arrives. This will result in the germination of millions of weed seeds and the prompt finish of the tiny plants. In any case the ground should be worked down until the soil is fine and the surface level and smooth.

After experimenting with different methods of application, the Experiment Station now favors and practices drilling in commercial fertilizer by the use of a common grain drill with fertilizer attachment. This is done after the ground has been harrowed once or twice and just previous to planting, where early planting is the rule. In case of late planting on early prepared ground a greater number of harrowings would, of course, precede the fertilizer application, which would be delayed until planting time. By this means of application the fertilizer is distributed evenly over (or rather in) the entire area where the feeding roots of the potatoes will readily find it as they freely extend through the upper soil. By this uniform distribution of the fertilizer the potato plants not only more fully profit by the application, but the surplus food, left in the soil after the maturity of the potatoes, will be evenly distributed for the wheat, rye or other crop which may follow. The modern horse potato planters are almost invariably provided with fertilizer attachments, planned only for distributing the fertilizer in the bottom of the furrow in a comparatively narrow line. While the crop, of course, benefits from this application, it does not by any means do so to the extent that would be possible were the plant food spread throughout the soil. Only a comparatively small percentage of the potato roots are found within the restricted limits of the three or four inch wide strips extending beneath the rows of plants. True the feeding roots of plants, according to one of the laws of nature, to some extent are attracted toward, concentrate and multiply about these rich sources of available plant food; but such concentration clearly means a greater or lesser degree of congestion or crowding and a corresponding and unusual drain upon the soil moisture of these restricted areas. This, especially in seasons of severe drought, is a condition of the feeding root systems of our plants not especially desirable and preferably not invited.

It is, of course, impracticable in planting by hand, small or garden areas for home use, to use a grain drill for applying the fertilizer. In these small patches it is a most excellent plan to open the

furrows with a large, broad-bladed, single shovel plow, leaving furrows approximately six inches deep and twelve inches broad at the top. The fertilizer is then applied by hand, scattering it not only in the bottom of the large furrow, but covering the sides or slopes as well. When the potatoes are planted in this furrow, covered, and the ground levelled down with a fine tooth harrow or cultivator, there will be spaces fully a foot wide along and beneath the rows, in which the fertilizer will be well distributed and mixed with the soil.

NORTHERN VERSUS HOME GROWN SEED POTATOES.

STORAGE

The widely prevailing belief that there is some special quality of superiority in northern grown potato seed stock, not possessed by our home grown seed, is responsible for many thousands of dollars being annually expended by Ohio potato growers for "northern grown stock." The Experiment Station is frequently called upon (especially by beginners in potato culture) to state whether there is just cause for entertaining such a belief and adhering to such practice.

It must be admitted that there is more or less abuse of the phrase "northern grown;" it is wonderfully elastic as commonly employed in the trade, and may signify much, considerable, little, or nothing at all. Maine, Vermont, Michigan or Wisconsin grown potatoes are truly "northern grown" stock as received and used by Ohio planters. Ohio grown stock is truly "northern grown" when used by planters in the southern states. Seed tubers produced in the Lake Erie district might, with some justification, be sold as "northern grown" to southern Ohio growers. But frankness prompts the suggestion that an indiscriminate selling, by dealers and seedsmen, of Ohio grown stock to Ohio planters, as "northern grown," approaches a travesty on the seedsmen's trade; it borders closely on deception and the getting of money under false pretence; it is, to say the least, making use of a "magic phrase" that has come to mean too much to the buying public and too little in reality. Happily, when the Ohio purchaser seeks northern grown potatoes and is supplied with Ohio grown stock that is plump, sound, bright and dormant; and if the conscience of the dealer become not a source of annoyance at these bits of deception, no one is materially injured —least of all the buyer; for, if the seed be as I described—well preserved and dormant—he will have secured as good stock for planting as the continent produces. But let us insist that this commodity be placed on the market for what it is; and let us judge its value as seed stock by its apparent purity as to variety and by its *condition* rather than by its source.

Excellence or inferiority of potato seed stock, therefore, depends vastly more upon its condition at the time of planting than upon the latitude or locality in which it was grown. The reason that northern grown stock has come to be noted for its superiority for a more southern latitude is because the seed is wintered in a lower degree of temperature in the more northern sections; it is kept sound and hard, crisp, fresh and dormant, and comes down to us at or just previous to planting time in this most desirable condition. It has lost none of its vitality through sprouting in storage. But, if seed tubers of our own growing be given similar storage conditions and is plump and dormant when spring comes, these are equal to the best stock in the market, no matter how far north it may have been produced. However, too often, our seed stock is wintered in too warm a storage, where it exhausts its vitality and becomes withered and shrunken through excessive sprouting. Especially is this true of stock wintered in cellars under dwellings.

The problem of storage, therefore, becomes the chief consideration and the determining factor of success as against failure for the professional potato seed grower, the dealer and the home or market grower who desires to produce his own seed stock. It is an especially important matter with the grower who is interested in the improvement of his favorite variety or varieties by careful selection from year to year. He must preserve his stock from season to season and preserve it in good condition if he maintain a continuity of the fascinating work and marked progress he is achieving in his chosen line of potato breeding. Those who make a practice of annually buying seed from another latitude or section as a rule do not realize or recognize the possibilities of, nor attach great importance to seed selection; and even if they do, it is not possible for them to take part in the maintenance of the high standard of a variety or its improvement by the potent means of selection of superior strains of that variety.

Not only extended observation, but carefully conducted tests at the Ohio Station, have shown that far northern grown potato seed stock is not superior to Ohio grown seed, if our home grown seed is well preserved. Bovee, Happy Medium, Gold Coin and Carman No. 3, seed from Maine, Michigan and Wisconsin was, in 1905, planted alongside seed taken from the cool, barn-basement storage on the Station grounds. The growing and yielding qualities of the home-grown stock was in every point fully equal to the northern grown seed. No more uniform plots could have been grown had the different plots of the same varieties been planted from the same seed-lots. But it must be admitted that our Station grown seed was in equally

as good condition at the time of planting as that from the more northern and colder latitudes. Had the seed of our own growing been robbed of its vitality by becoming excessively sprouted in a too warm storage, and withered and shrunken as too often home grown seed stock becomes, the results would doubtless have been in favor of the northern grown seed stock, as has often been proved in comparative tests.

A cellar or basement under the barn or some similar farm building can usually be converted into a suitable storage for seed potatoes. Storage cellars under outbuildings are much cooler than those under dwellings. The temperature of such a potato storage may quite readily be held at from 34 to 40 degrees, by reasonably careful attention. When a dangerously low degree of cold is threatening, a lantern, or small, oil stove may be kept burning in the storage room. To guard against possible danger from explosion, or overturning of the lantern or stove, and spreading of oil, the heating device should be set in a large metal pan, or a metal tub. If the temperature of the storage ascends to 40 degrees or above, through the influence of unusually high, daytime temperature, the outside doors or the ventilators should be thrown open during the colder temperature prevailing through the night time. This will usually lower the temperature of the storage and its contents to the desired degree. All outside openings should be provided with fine-meshed wire screens to exclude vermin when the outside doors are open.

Underground storage rooms or "caves," built in a hillside or on well-drained level situations, may be made to do excellent service for potato seed storage. The same means of controlling the temperature of these, as used in cellars of outbuildings, may be employed.

Potatoes may also be buried in out-door pits and kept in fine condition until planting time. A well drained location should be chosen for the pit—one from which the surface water will readily run away. The tubers are piled in conical, pyramidal or long, sharp-ridged heaps, and covered over with six or eight inches of clean straw. Over the straw is covered about six inches of soil. Straw is also spread on the ground in a circle a little distance back from the base of the pit; this is to prevent the ground thus covered from freezing, so that more soil may be readily available when desired. As soon as the first covering of the soil over the pit has become solidly frozen a second covering of straw is added, and over the straw another six inches of soil. The second stratum of soil is then allowed to freeze solid, after which a layer of bundles of corn stover or a heavy covering of straw is placed around or over the pit, to shade and maintain the low degree of temperature prevailing within. Potatoes wintered in this way come out clean, plump, fresh and unsprouted at planting time.

It is evident that as the preservation of seed potatoes in good condition for planting becomes more and more difficult as the southern limit of Ohio is reached, the advisability of procuring seed from more northern sections becomes a more important consideration unless some plan of cold storage is available. But in the northern two-thirds of our state, no great difficulty need be experienced in keeping home grown stock in good condition in carefully constructed outbuildings or barn storage rooms. Growers in the southern states resort to growing a second crop of potatoes from the seed of the first crop, in a single season. The second crop seed keeps in good condition for the next season's planting. This plan is not practicable for our latitude; but late planting of "sun-sprouted" seed tubers may be substituted, and an excellent quality of long-keeping seed stock produced for the following year's planting. Such seed stock is fully equal to second crop southern seed, and is better than much of the so-called northern grown seed found in the market.

"SUN-SPROUTING" SEED POTATOES AS A MEANS OF PRESERVATION AND PREPARATION FOR PLANTING

While it is impossible to preserve seed potatoes in good condition in a storage which combines a too high degree of temperature with darkness, semi-darkness or even slightly subdued light, it is quite possible to keep them for several weeks, in late spring or early summer, when they are spread thinly on the floor of a bright sunny room. After danger of freezing weather is past they are even better placed out of doors in the direct sunshine. A series of shelves arranged one above another on the southern exposure of the dwelling or a farm building provides an excellent place for sun sprouting. The tubers are spread in single layers on the shelves and allowed to remain until wanted for planting. Exposed to the full force of the sun's rays the tubers, instead of sending out long, white, tender, succulent sprouts as in poorly lighted storage, become hardened in

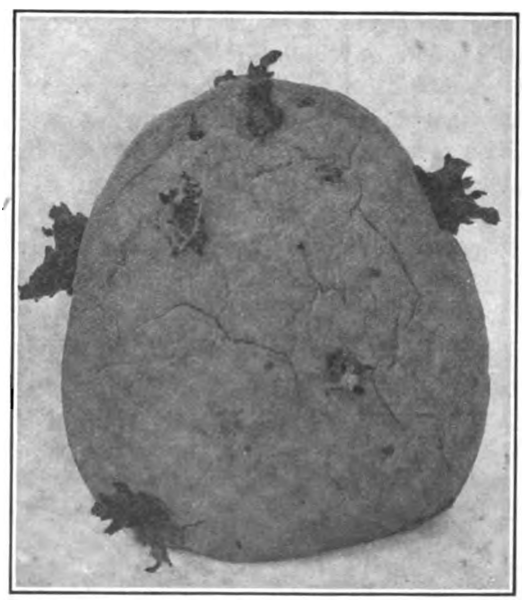


Fig. 1. Tuber exposed to direct sunlight for four weeks.

flesh and green in color, and very short, stubby, firm, green sprouts are developed by the eyes. Withering of the tubers is but slight as compared with that under conditions found in a warm, dark storage, and they will remain in the sunlight many weeks in good condition for planting. Photographs are herewith presented showing one tuber that was exposed to the sunlight four weeks and another that was exposed ten weeks. Such tubers, when cut one sprout to a piece and planted, send up strong plants in a surprisingly short time.

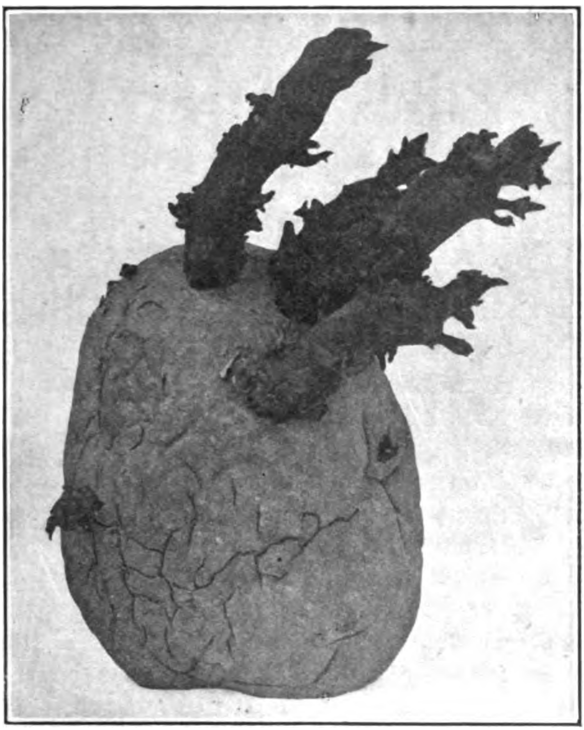


Fig. 2. Tuber exposed to direct sunligut for ten weeks.

It is hardly profitable to sun sprout large tubers for planting, as not all of the eyes will develop sprouts and considerable waste will result. However, the plan is excellent when smaller tubers are used and planted without cutting. So firm and tough become the hard short, sturdy sprouts developed in the sun, that planting may be done with certain horse-power machines without injury to the seed tubers if not too many are placed in the planter at a time. Planting of sun-sprouted seed is often delayed as late as the early part of July with excellent results in the production of a fine quality of seed stock for the following year.

Seed stock subjected to the prolonged "sun bath" does not require treatment for tuber infesting fungi, with formalin or corrosive sublimate. Bright, hot sunshine is, in itself, an effective fungicide. However, the usual recommended treatment with formalin seems not to produce any injury to the firm, green sprouts, as determined by a test in the season of 1908.

By the plan of sprouting the tubers of first early varieties in a sunny room early in the spring, the season of new potatoes for table use can be hastened nearly or quite two weeks, as was also demonstrated in 1908 in a comparison of sun-sprouted seed with ordinary cellar stored stock.

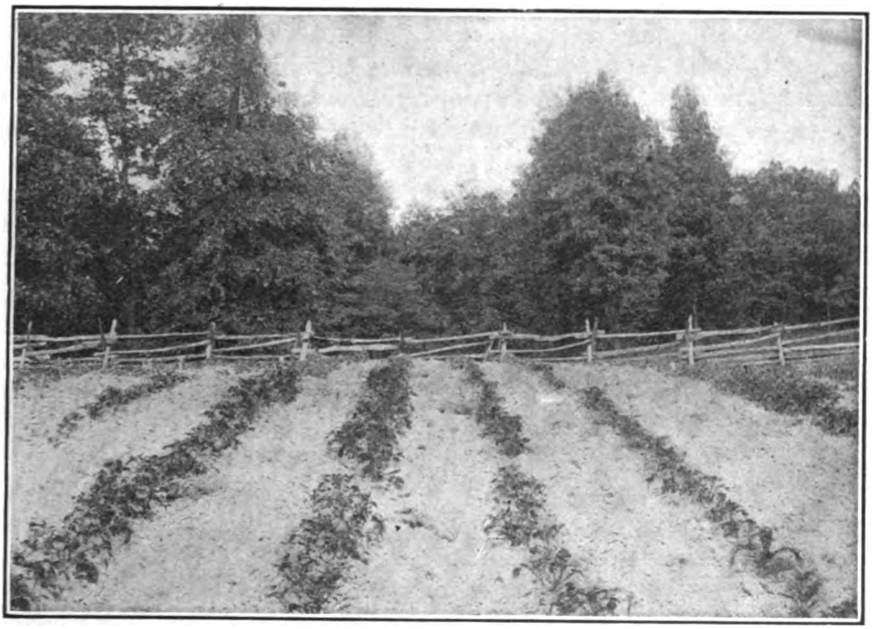
EXPERIMENTS WITH DIFFERENT QUANTITIES OF SEED POTATOES PER ACRE

The principle test work with potatoes in the season of 1906-1907, aside from the regular fertilizer and variety experiments, was the comparison of different quantities of seed per acre (determined by the different sized seed pieces used) planted in adjoining uniform plots of soil. The work was taken up in response to numerous inquiries from correspondents, and conducted with the utmost care and interest.

In this experiment were used, the first year, 10, 15, 25 and 40 bushels per acre, planting two standard varieties, Bovee and Carman No. 3, and duplicating the work in full so that dependable average results might be obtained. The second year's work was a duplication of that of the first year with the exception of one additional plot, representing a different rate of seeding with a different class of seed tubers not used the first season. This will be explained in its proper place.

The seed pieces were very carefully cut and accurately weighed in each and every rate of planting. In the 10 bushels per acre rows one-eye seed-pieces were used; in the 15 bushels per acre, two eyes; in the 25 bushels per acre, half tubers, and in the 40 bushels per acre whole tubers. The tubers throughout were smooth, of fine form and as nearly uniform in size as it was possible to have them in order to secure the desired weights from the different sized seed pieces. In order to overcome the now generally recognized tendency of plants to perpetuate, in the new generation, individual characteristics whether these be desirable or objectionable, not more than one seed piece from a divided tuber was permitted to be planted in a single test row. As an illustration: In the selection of seed tubers it is quite likely that we shall unwittingly choose an occasional tuber that was grown from a seed piece that produced in the hill a very small number of tubers. Perchance the

tuber we have chosen for planting was the only one of acceptable size produced by its parent plant; we do not and cannot know, unless we had selected the seed tubers from individual plants or hills the preceding season. Assuming that the unproductiveness of that particular hill was inherited from the parent seed stock, it is evident that we should make a grave mistake in dividing possibly the only good tuber from that hill and using it for planting a consecutive number of hills in a single test row. What is true of a tuber of inherent unproductiveness is also true of a tuber of inherent prolificacy.



40 bu. per acre 25 bu. per acre 15 bu. per acre 10 bu. per acre

Fig. 3. Heavy and light seeding.

Therefore, in order to render our test of more value and dependence, we first cut a tuber in halves. One half was used to plant one hill in in the 25 bushels per acre section. One eye out of the remaining half went to form a hill in the 10 bushels per acre section. A two-eye piece from the same half-tuber found its way to a hill in the 15 bushels per acre section. If there were any eyes left from that particular half-tuber, they were discarded. Each hill of the 40 bushels per acre section of course required a whole or individual tuber, hence there was no division and no great danger of duplication of seed tubers from the same parent plant.

It was interesting to note the difference between the young plants of the different sections, as they pushed up through the soil in due time after planting. The difference in vigor of plants, for the first week or two, was decidedly in favor of the whole tubers. The plants from the one-eye pieces were at first much more slender than those from the two-eye pieces, half-tubers or whole tubers. These more delicate plants required greater care in the first cultivation, but the difference was not so apparent later on as the plants gained in size and vigor, and by the height of the growing season the individual stalks from the single-eye pieces were as large and strong as the stalks from the larger seed pieces.

As the rate of seeding per acre was increased, depending on the size of seed pieces used, in like proportion was the average number of plants or stalks per hill increased. Increasing the size of potato seed pieces, therefore, (with a corresponding addition to or multiplication of the number of eyes contained) is equivalent to increasing the number of grains per hill in seeding corn; and from extended observation in the past as well as from experiments conducted to obtain data for this bulletin, the results in either case may reasonably be expected to prove similar. By increasing the number of stalks per hill (up to a certain limit) the total yield may be somewhat enlarged, but this gain in yield is often at the expense of the size, development and quality of the product—whether this product be potato tubers or ears of corn. The following table shows the average number of potato stalks per hill from the different sized seed pieces used. One row of 45 hills was counted in each section:

BOVEE

Size of seed pieces	Rate of seeding	Total number of stalks in one row of 45 hills	Average number stalks per hill
One eye	10 bus. per acre	94	2+
Two eyes	15 "	144	3+
Half-tubers	25 "	282	6+
Whole tubers	40 "	495	11
Small tubers (2 oz.)	22.6 "	356	7+
CARMAN No. 3			
One eye	10 bus. per acre	92	2+
Two eyes	15 "	142	3+
Half tubers	25 "	181	4+
Whole tubers	40 "	232	5+
Small tubers (2 oz.)	22.6 "	183	4+

It will be noted that in the above table that the large seed pieces of Bovee produced a correspondingly increased number of stalks to the hill, while the Carman No. 3 does not exhibit this tendency in

nearly so marked a degree. Indeed the Carman, as a representative of a distinct type of potatoes to which many varieties belong, is widely different from the Bovee, which is likewise representative of another type or family. It is almost impossible to cause the Carman to crowd in the hill, from the planting of a single seed piece, no matter how large. A whole tuber of good size may produce but two or three strong stalks, while had that same tuber been divided into one- or two-eye pieces each piece would likely have produced an equal number of strong shoots. It can hardly be said that the buds or eyes of the Carman lack vigor, but it is true that there is a tendency for a good percentage of the eyes to remain dormant in a whole or half tuber when planted, while further cutting of the same tuber—the isolation of each single eye—would have resulted in a full percentage of growth. On the other hand the Bovee represents a class of varieties which may be said to be free and profuse in their habit of sprouting or germination, as has already been demonstrated in the accompanying table.

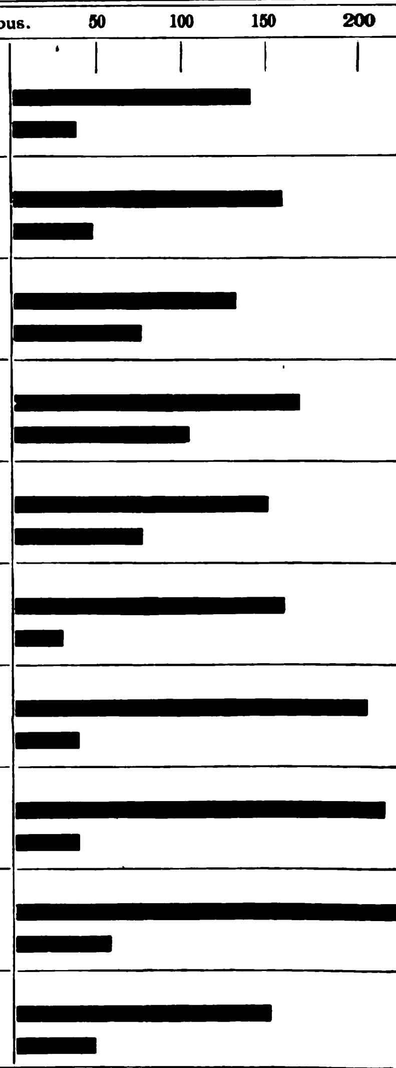
As to the time of maturity, in the different sections of the same varieties, there seemed not to be a noticable difference, although it has been observed by some experimenters that while plants from whole tubers do not mature earlier in the season, there may be obtained from hills grown from whole tubers new potatoes of usable or marketable size earlier in the season than from piece planting.

The following table presents, in a form convenient for comparison, the average results of two years' experiments (1906-1907) with different quantities of seed potatoes per acre. The test of small tubers, as noted in the table, was included only in the test of the second season (1907). The addition of this test of small tubers was and is considered a feature of but minor importance. The figures are given only as a matter of interest.

It will at once be noticed that with the Bovee the yield of small or "unmarketable" tubers (tubers less than two ounces in weight) increases quite uniformly as the size of the seed pieces and quantity of seed per acre are increased. This is not apparent with the Carman, clearly for reasons already given with reference to the Carman's peculiar nature or habit of restricted sprouting or "germination."

TABLE SHOWING RESULTS OF USING DIFFERENT QUANTITIES OF SEED POTATOES PER ACRE. AVERAGE FOR TWO YEARS

		Yield per acre, bus.
Bovee (one eye)	10 bushels per acre marketable	146.6
	unmarketable	32.7
Bovee (two eyes)	15 bushels per acre marketable	159.1
	unmarketable	45.5
Bovee (half tubers)	25 bushels per acre marketable	131.7
	unmarketable	73.5
Bovee (whole tubers)	40 bushels per acre marketable	168.7
	unmarketable	99.4
Bovee (small or 2 oz. tubers)	22.6 bushels per acre marketable	150.1
	unmarketable	73.5
Carman No. 3 (one eye)	10 bushels per acre marketable	164.2
	unmarketable	25.1
Carman No. 3 (two eyes)	15 bushels per acre marketable	204.3
	unmarketable	31.7
Carman No. 3 (half tubers)	25 bushels per acre marketable	217.1
	unmarketable	35.7
Carman No. 3 (whole tubers)	40 bushels per acre marketable	223.0
	unmarketable	51.8
Carman No. 3 (small or 2 oz. tubers)	22.6 bushels per acre marketable	145.2
	unmarketable	48.2



Upon a basis of dollars and cents, we find that the Bovee, at the fair, average price of 50 cents per bushel both for the seed used and the product grown:

15 bushels of seed per acre gave a gain of $ 3.75 over the 10 bushels.
15 bushels of seed per acre gave a gain of 18.70 over the 25 bushels.
15 bushels of seed per acre gave a gain of 7.70 over the 40 bushels.

With the Carman No. 3, at the same price per bushel:

15 bushels of seed per acre gave a gain of $17.55 over the 10 bushels.
25 bushels of seed per acre gave a gain of 1.40 over the 15 bushels.
15 bushels of seed per acre gave a gain of 3.15 over the 40 bushels.

In these calculations the value of the *excess* of seed, where the larger quantities were used, was of course taken into consideration.

There yet remains a very important feature to be explained which the foregoing table does not exhibit. This matter pertains to the size, uniformity and beauty of the tubers; these qualities figure largely when the product goes upon the market—especially a dis-

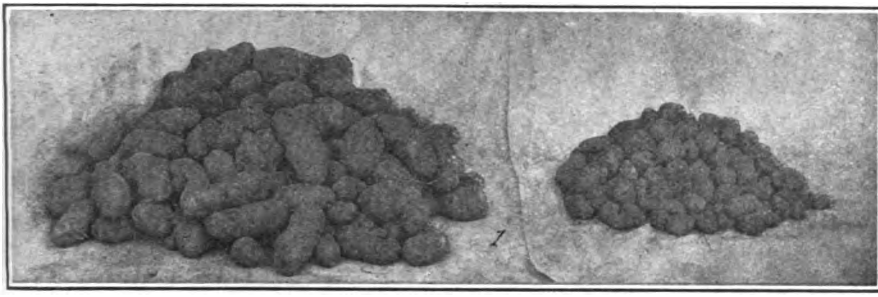


Fig. 4. Bovee. Product of seeding at rate of 10 bus. per acre—one-eye seed pieces.

criminating, retail market. In every case the tubers grown from the one- and two-eye seed pieces, while somewhat less in number, average far above those grown from the heavier rates of seeding. For the cause of this we have only to refer to the table showing the proportionate increase of the number of stalks or plants per hill as the quantity of seed per acre is increased by using larger seed pieces. It becomes

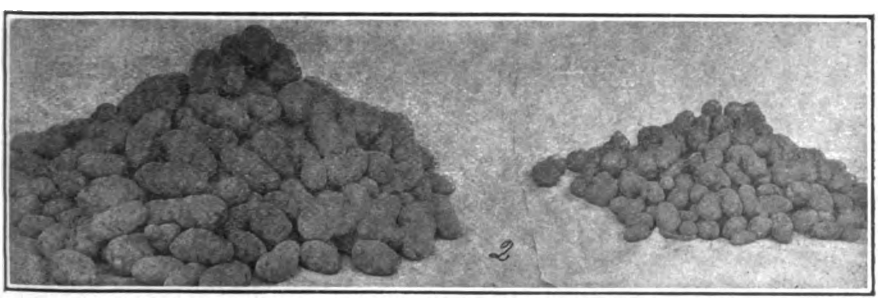


Fig. 5. Bouee. Product of seeding at rate of 15 bus. per acre—two-eye seed pieces.

clear that a surplus potato stalk in a hill of potatoes is just as a surplus stalk of corn in a hill of corn; it is a "weed plant;" and while its presence may or may not lower the total yield, in weight or bulk, of the hill in which it occurs, its presence will detract from size, the fullest development and sightliness of the individual tubers produced in that hill. The photographs which follow show conclusively that the

quality of the product declines as the rate of seeding per acre increases, even though the scales and the bushel measure may indicate a greater or lesser increase in the total weight or bulk.

Inasmuch as whole, small or two ounce tubers were used in 1907 in comparison with the one- and two-eye seed pieces and the half-tubers and whole tubers (all from select stock) it will, perhaps, be

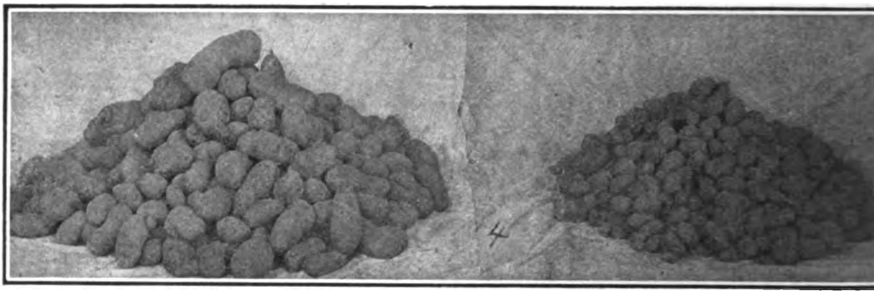


Fig. 6. Bovee. Product of seeding at rate of 25 bus. per acre—half-tuber seed pieces.

well to include a brief statement relative to results. For reasons which will be made clear in the chapter on potato seed selection and improvement, the writer does not care to spend much time with small tubers as a basis of experimental work with potatoes, nor valuable space in discussing them. However, it has been urged by some growers (and it is true) that small potatoes used for seed

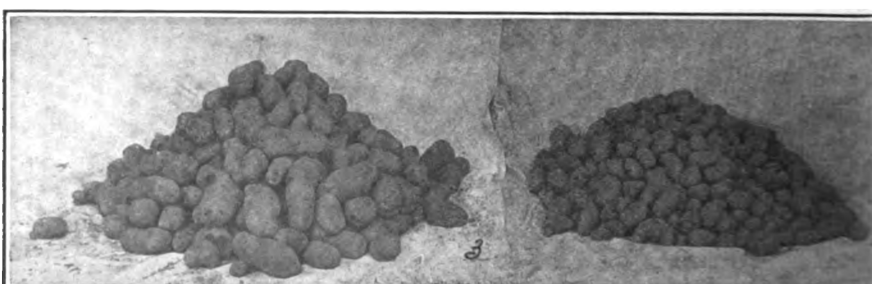


Fig. 7. Bovee. Product of seeding at rate of 40 bus. per acre—whole tubers for seed.

materially cuts down the expense of crop production, because of such stock not being marketable—because it would otherwise represent a by-product, a waste, a loss in the business of the market grower. Certainly economy in every industry is to be commended and encouraged so long as such economy does not foster a menace for the future. So long as the grower produces stock for a market

that caters solely to the country's food supply and chooses to use the culls, the screenings, the chaff of his successive crops for seed we can hardly object; but when he repeatedly uses such seed stock and disposes of his product to seed dealers who distribute it far and wide as pure, well-bred, high-class seed stock, the thread of truth, honor, discretion and safety is strained wellnigh to, if not beyond the breaking point.

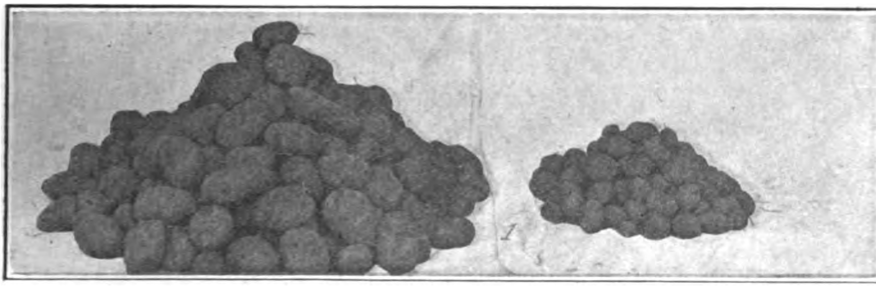


Fig. 9. Carman. Product of seeeing at rate of 15 bus. per acre—two-eye seed pieces.

Small seed potatoes, planted whole, often produce as great a bulk of tubers that can be passed into the marketable grade, as piece-planting of good sized tubers; but, taken as a whole, the character of the marketable stock grown from small tubers is far below that produced from one- or two-eye pieces of larger and uniform seed stock.

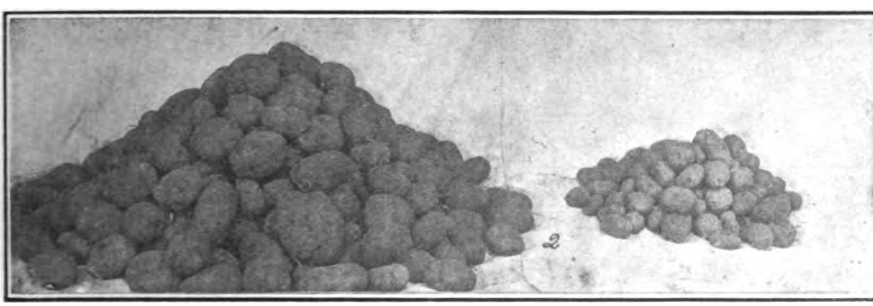


Fig. 8. Carman. Product of seeding at rate of 10 bus. per acre—one-eye seed pieces.

These results have been observed again and again; it needed no field test to prove what has been seen year after year in various sections. Therefore, as was anticipated, just such results were found very marked in the test plots of 1907. The marketable quantities from the small seed tubers compared well with the marketable quantities from the different rates of seeding from large tubers, but the aver-

age size of the tubers that composed the marketable product from the small seed was very noticably inferior to the product of one- and two-eye pieces of the same varieties grown in adjoining plots, while

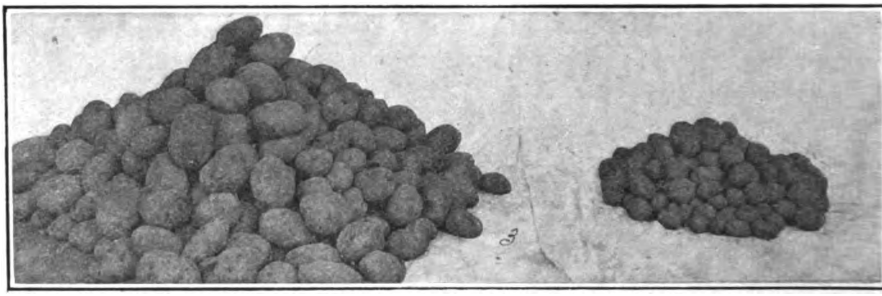


Fig. 10. Carman. Product of seeding at rate of 25 bus. per acre—half-tuber seed pieces.

the proportion of small or unmarketable tubers was greater in both Bovee and Carman No. 3 than from any of the rates of seeding save that of 40 bushels per acre where the large, whole tubers were

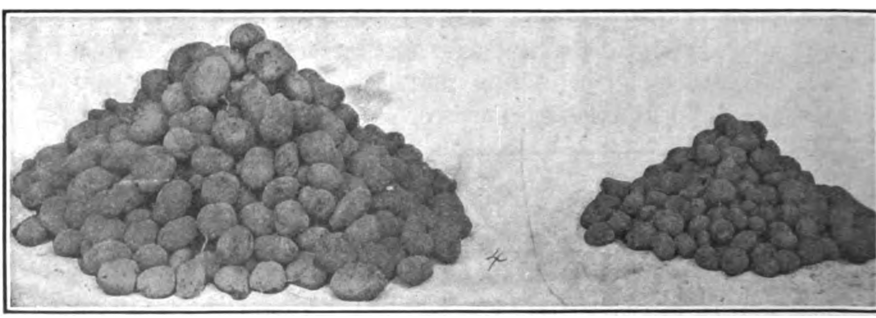


Fig. 11. Carman. Product of seeding at rate of 40 bus. per acre—whole tubers for seed.

used. The crowding of the plants in the hill where small, whole seed was used, was but little less than where the whole, large tubers were planted—as might well be expected from the fact that a small tuber contains as many eyes as that same tuber would have contained had it grown to much greater size.

POTATO SEED SELECTION AND IMPROVEMENT. TUBER ROW AND HILL-ROW TESTS

By far the greater number of new varieties of potatoes originate as seedlings; this is true also of most varieties of vegetables, fruits and cereals. Many potato growers insist that a variety possesses a fixed character; that its attributes—excellent, mediocre or inferior—are determined for all time at its origin, its birth; that it remains absolutely unchangeable so long as it is, through the exercise of proper care, propagated and perpetuated in purity. Certain others

maintain that even though a variety possess all the qualifications of an ideal potato at and immediately subsequent to its origination it will, as time passes, gradually decline in vitality, prolificacy and quality until it is no longer of value; that it will, to use a common phrase, "run out." Still others, and in this class are included our practical and scientific plant breeders, recognize the fact that there are no duplications in nature; that no two plants of the same variety, divisions of the same plant, or buds of the same division are absolutely identical either in physical construction or power to reproduce. Each plant, division, branch and bud possesses an individuality which renders it more or less different from others of its kind. This is termed *natural plant variation*. Such variations, it is true, are usually so slight, so generally unnoticeable, as rarely to attract attention from the casual observer; but there are no set boundaries, no marks of limitation, within which the individuality of a plant may safely be declared to assert itself. Nine hundred and ninety-nine plants of a certain variety may be stamped each with its own peculiar though perhaps well nigh inscrutable personality, while the one-thousandth individual may manifest so little regard for family precedent, example or influence as to bound so high above or descend so far below the average of its companions in performance or appearance, or both, as to establish a new record for excellence or utter worthlessness never before approached by an individual plant of that variety. It has, indeed, sprung so far without the usual limits of performance of its parent type as to warrant its being declared a new variety. This greater variation of plants is technically known as *mutation*, though the terms "bud sporting" and "freaking" are commonly applied. To mutation was due the origin of the White Seneca Beauty or *Livingston* potato, which was discovered as a white skinned tuber in a hill of red Senecas—an excellent example of "sporting." Other examples of varieties of fruits and vegetables originating in this manner might be given. If this remarkable breaking away from varietal boundaries has been in the direction of improvement, the new variety will be accorded an appreciative reception at the hands of the culturists; it will become widely known and profitably grown. If, on the other hand, the extreme variation brings with it only inferiority as compared with the original, average or parent type (which is more often true) it may well be lost to cultivation, as it surely will be.

Therefore, through extreme bud variation or mutation may a new variety be born as truly as from seed. Likewise, through the lesser, though still clearly marked mutations, may a variety improve or degenerate without losing its identity with the parent variety; and it

is upon this natural variation of plants—even the lesser variations—that the plant breeder bases his reasonable hope of success in the betterment of already standard and favorite varieties, by selection of such strains as give promise of retaining the desirable and eliminating the undesirable characteristics of the original type. Such improvements are already accredited to not a few of our thoughtful careful, potato breeders.

We have, then, in view of the fact of universal plant variation, to unlearn the old adage that "like begets like." Instead, at the very outset of our effort to improve varieties by selection, let us assure ourselves that, as a rule and at best, similarity begets similarity; that a variety is composed of a great number of strains; that the older a variety may be the greater will be this multiplication of strains, that these multitudinous strains will represent all gradations of value from the superior to the inferior, yet possibly all be sufficiently similar to the original type to justify us in maintaining that the variety is pure.

What would be the result, therefore, of separating the superior strains of a variety of potato, as represented by perfectly formed tubers from high-yielding hills, from the commonplace and inferior and planting these separately? The yielding power, uniformity and appearance of that variety would at once show marked improvement. On the other hand if the inferior strains, as represented by the small, imperfectly formed tubers from low-yielding hills, be separated from the superior strains and used for seed, the yielding power will be reduced and the uniformity and appearance will exhibit marked deterioration.

It is for the purpose of separating the superior from the commonplace and inferior that the several plans for selection of seed stock have been devised. Let us carefully note at least two of these schemes:

It often happens that the interest of the potato grower in potato seed improvement is awakened only at or near the time of planting. His only recourse at such a time is to choose his seed from the bulk or "bin" of the storage. This plan is open to well founded objections as compared with choosing seed stock from individual hills in the field at the time of digging, but it is vastly more to be commended than failure to choose at all. Let us see wherein lies the weakness of selecting even the choicest appearing tubers from the bin or bulk. It is evident that the planter will accept only those specimens which appeal to him as representative or typical of the variety with which he is concerned; they must be smooth, uniform and bear indications of vitality as evidenced by soundness and well-developed eyes. But

he has no means of determining whether a tuber answering these requirements in appearance was *one of several similar ones* in a high-yielding hill, or the *only one* of its size in a low-yielding hill. It would really be to his future interest and profit to separate these strains, retaining the prolific and discarding the unproductive. The tuber-row-test will prove this point and he will proceed as follows:

Cut each of the selected tubers to uniform, one-eye pieces. It is not difficult to find tubers of almost any variety that will each afford ten such seed-pieces; but let the number of seed-pieces from each selected tuber be such that the test rows planted from each will be uniform in length and number of hills. Plant these tuber-test-rows with one seed-piece to a hill, the hills 16 inches apart and marked with a numbered stake driven securely in the ground, on as nearly uniform soil as can be chosen. Give the same care in the way of fertilization, cultivation and spraying to all the rows composing the tuber tests. There is no limit to the number of tuber rows which may thus be included in the trial plot; but it is a significant fact that the greater the number of tubers thus planted the greater will be the number of striking variations sure to be exhibited both in habit of growth of the plants and in yields; and also the more extended will be the opportunity of obtaining a number of superior strains of the variety being studied. At digging time the product of each test-row should be weighed and the weight as well as the general characteristics of the product carefully compared with those of its companion rows. The more excellent lots may be distinctly labelled by numbers and kept in separate crates for a second trial upon a more extended scale; or, if but one season's trial be all that it be desired to make, the superior yielding strains may be thrown together, thus forming a composite seed lot to be planted the following season in comparison with ordinary or unselected stock. This is not recommended, however, in careful potato selection; the isolation of separate strains should be maintained until the one superior strain is determined by repeated tests. The second season's test should be in duplicate—that is, one-half the seed of a certain tuber-product should be planted in Row No. 1 in Section A, and the other half in Row No. 1 in Section B in another part of the field or area. Average results in yield under different conditions are thus obtained from each strain.

The ideal method of inaugurating an experiment in potato seed selection is to make the original selection in the field at the time of digging the crop. Several hundred hills should be dug in a representative portion of the field, each hill being thrown by itself. After the separate hill products are thus exposed a careful selection of individual hills should be made, choosing only such hills as contain

a satisfactory yield of uniform, marketable tubers which are typical of the variety to which they belong. It is well to keep in mind that a hill of potatoes may be good because it is inherently good, or it may be good because of certain conditions of the soil or of other environment which have affected that hill alone. A few small tubers in a hill should be no objection to the choosing of that hill, providing that hill contains a liberal yield of good, representative, marketable tubers. Each hill chosen should be bagged separately and numbered consecutively. Muslin bags are preferable, though strong, paper bags may be made to answer. The muslin bags are superior because the hill selections contained therein can not only be readily and safely stored in covered, mouse-proof barrels, but at planting time the seed can be treated in the bags with formalin or corrosive sublimate, by throwing the bags of seed into the solution. With paper bags this cannot be done without their breaking and causing mixture of the potatoes.

At planting time from each hill of tubers is cut a certain number of uniform, one-eye seed-pieces. It is quite easy to obtain from an average hill 20 of these seed-pieces. Duplicate test rows, each containing 10 seed-pieces planted one eye to a hill and the hills 16 inches apart, are planted from each parent hill, on uniform soil. As an illustration from parent hill No. 1 are cut 20 one-eye seed-pieces; ten of these single-eye pieces are planted in hill-row No. 1 in Section A; the remaining 10 similar pieces are likewise planted in hill-row No. 1, Section B (the duplicate). Parent hill No. 2 likewise goes to plant hill-row No. 2 in Section A and hill-row No. 2 in Section B. Every fifth or sixth row in both Section A and Section B is planted with good tubers taken at random from bin or bulk, cut to one-eye pieces and so distributed in the various check rows that but one seed-piece from each tuber will be planted in the same check row. Twenty such tubers, each cut to 10 single eye pieces, will suffice to plant 20 check rows of 10 hills each with no two hills in the same check row planted from the same tuber. In detail, "check tuber" No. 1 cut to 10 one-eye pieces may be used to plant hills No. 1 in ten different check rows; "check tuber" No. 2 cut in the same way will go to plant hills No. 2 in the ten different check rows, etc. The object of the check rows is to afford a standard or average made up of composite seed stock, with which to compare the yields from the differet rows planted from selected parent hills. The following diagram, the writer trusts, will assist in rendering the plan of a duplicated hill-row test plot readily interpreted.

PLAN OF A HILL-TO-A-ROW TEST FOR POTATOES

		Section A										Section B (Duplicate)									
Hill-rows	1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	3	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	4	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Check-row	1	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Hill-rows	6	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	8	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	9	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	10	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Check-row	2	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o

Well marked results in potato seed selection, as determined by the hill-row test plots, have been secured at the Ohio Station, both in selection for high yields of tubers and for disease resistance of plants. The work was begun under the supervision of Mr. C. W. Waid, in 1903, by selecting:

(1) A series of heavy producing hills of Carman No. 3, regardless of the character of the plants producing such yields.

(2) A corresponding series af hills of the low yielding or common stock of Carman No. 3 for comparison, regardless of the character of the plants producing the same.

(3) A series of hills of Whiton's White Mammoth, the plants of which exhibited marked resistance or immunity against blight, which was prevalent in the field in 1903.

(4) A corresponding series of hills of Whiton's White Mammoth the plants of which were destroyed by late blight in the season of 1903.

Records of yields from individual hills and their progeny, of these various lots, were secured by Mr. Waid during the seasons of 1904-5-6, all individual hill products keing kept separate during that time. In the spring of 1907 the writer was given charge of the work and the now great number of selected seed lots for the purpose of determining, under field conditions, what had really been gained by the original hill selection and the great amount of painstaking work of the succeeding three years. The first move in the enlargement of the scope of the work was to take from the hundreds of separately preserved hill-lots of seed:

(1) Seventy representative hills of the high yielding strains of Carman No. 3, which weighed in total, 94 pounds.

(2) Seventy representative hills of the lower yielding or common strains of Carman No. 3, which weighed, in total, 36 pounds.

Composite seed lots were made by mixing together the 70 hills of high-yielding strains; also by mixing together the 70 hills of low yielding strains or common stock. Sufficient seed was taken from these two separate lots to plant four rows of the high-yielding strains and two rows of the common strains for comparison. Care was exercised to have the tubers of the respective lots as uniform in size, form and appearance as could be selected. This accounts for the unequal number of rows planted, as from the 70 hills of the common strains there could not be found a sufficient number of tubers that would grade up to the required standard of size to plant four rows, or the number planted from the high-yielding strains. This fact in itself is a significant one and quite suggestive of the trend of results of the years 1904-5-6.

The following table exhibits the results of the field test of the selected and unselected Carman No. 3 for the year 1907. The rate of yield in bushels per acre was calculated upon a corrected or uniform stand of plants (or hills) per row:

	Row	Hills	Marketable Lbs.	Unmarketable Lbs.	Total Lbs.	Rate of yield per acre—Bus.
Selected strains	1	154	136	13	149	175.5
	2	171	151	10	161	170.5
Common	3	155	105¼	11¾	116	136.3
Selected strains	4	181	182½	8	190¼	190.9
	5	168	162¼	13¼	176¼	190.5
Common	6	172	76½	14½	91	96.0

Average per acre in total yield, selected strains, 181.9 bushels.
Average per acre in total yield, unselected strains, 116.15 bushels.

A similar though still more extensive field test was conducted in 1907, comparing the blight resistant strains of Whiton's White Mammoth with the non-resistant strains of the same variety. Comparisons of these resistant and non-resistant strains had been carefully carried on during the seasons of 1904-5-6., by Mr. Waid, just as had been done with the high yielding and common stock of Carman No. 3, all individual hill products being kept separate during this period. In 1907 composite seed lots were made up by throwing together and mixing the hill-product of the resistant strains; likewise the non-resistant strains. A plot of 12 rows was planted, embracing 8 rows of the resistant and 4 rows of the non-resistant stock. The following table shows the result of the field test, The rate of yield per acre is based on a corrected stand of plants or hills per row:

	Row	Hills	Marketable Lbs.	Unmarketable Lbs.	Total Lbs.	Yield per acre Bus.
Resistant	1	168	183	15	198	213.8
	2	175	179¼	12	191¼	198.1
Non-resistant	3	170	99½	15¼	114¾	122.5
Resistant	4	167	168¼	14	182¼	198.0
	5	162	178	15	193	200.6
Non-resistant	6	188	154	20	174	167.8
Resistant	7	174	188	14	202	210.5
	8	168	162½	17	179½	192.0
Non-resistant	9	171	140	15½	155½	164.9
Resistant	10	176	207	12½	219½	226.3
	11	168	182¼	10	192¼	207.6
Non-resistant	12	176	137½	16¾	154¼	158.9

Average yield per acre, disease resistant strain, 206.9 bushels.
Average yield per acre, disease non-resistant strain, 153.5 bushels.

The foregoing tables are sufficient to prove, quite within themselves, the value of potato seed selection. However, in addition, the writer is constrained to add that the 1907 field test plots of both Carman No. 3 and Whiton's White Mammoth were object lessons in demonstration of the effects of seed selection the whole season through. The high yielding Carmans, because of their superior vigor, could be distinguished from the common strains, even by a disinterested visitor, as far away as the plot could be seen. Likewise there was a remarkable difference between the rows of resistant and non-resistant W. W. Mammoth. This difference was more and more marked as the close of the growing season approached. The non-resistant rows of plants were quite dead in early September, while the resistant rows continued green, vigorous and growing until cut down by the frost some three weeks later. No spraying for blight was done on this plot as it was strictly a test of disease resistant versus non-resistant plants.

It may well be stated, furthermore, that experiments coupled with many observations suggest that little is to be gained by selection of parent hills of potatoes on the basis of disease resistance of the plants, over selection of parent hills because of the superior, individual yields. It is the actual work done within the hill that should most interest the potato breeder; the more promptly these desired results are accomplished by the plant the more desirable that strain. While, as the latter table shows, good results are obtained by selection of hills because of disease resistance—because of long standing and late growing in the field—it has not been apparent that this cause for selection is to be commended above the plan of selecting for prolificacy in the hill regardless of the character of the plants of

such hills. Indeed selection of long standing, late growing hills or plants should not be done unless blight or other disease is surely known to be present in the field and responsible for the premature breaking down of the majority of the plants; for, through natural variation of plants in which season of maturity as well as other characteristics are affected, there is grave danger of so lengthening the season of growth and development of that variety by choosing these late growing strains, that danger of non-maturity of crops may be thus invited for future years.

Many isolated, late growing hills of Carman No. 3 were dug from a 3-acre field on the Station grounds in the autumn of 1907 and compared with adjacent hills which ripened many days previously. In not a single case was the product of a late growing individual hill found to be greater or better in any way than equally vigorous hills which had more promptly closed their season of growth. Blight was not present in the field, however, and the later growing hills simply demonstrated that there develop, through natural plant variation, these tardy, deliberate, slow-maturing strains which we should not mistake for strains of special disease resistance.

SHALL WE USE THE SMALL POTATOES FOR SEED PURPOSES?

The question is often asked by potato growers, "What about using the small potatoes for seed?" This subject has already been touched upon in a preceding chapter. It is one of importance not only to the individual potato grower, but to the potato growing industry of our state and country at large.

As a regular practice there is no hesitation on the part of the writer in declaring that the use of the small or cull stock for seed is not to be seriously considered for a moment by the grower who would improve or maintain the quality of his stock. In a word, while the small tubers of a crop may include a *small percentage* of the standard strains composing a variety, it also includes all the worthless trash, all the "chaff" of an unselected variety, developed through years, perhaps decades of plant variation. Let us consider the matter from a simple illustration:

From a block of 1000 hills of common, unselected stock including high, moderate and low yielding strains of a given variety, seed for the succeeding year's planting is to be taken. Let us estimate that 800 of these hills fairly represent the average or moderate yielding strains of the variety; that 150 hills are below the average type—are low yielding strains; that 50 hills are above the average type—are superior high-yielding strains. It is reasonable to figure on this basis, for experiments have repeatedly shown that there is a greater

tendency, through natural plant variation, toward a falling below the average type of a variety than of rising above the same. Now, what would be the character of the seed stock chosen from the 1000 hills by the grower who insists upon careful selection of his seed and would accept only good sized uniform, representative, marketable tubers from the bin or bulk? His choice would include:

(a) A *very heavy*, perhaps almost *total percentage* of the *high yielding strains.*

(b) A *heavy percentage* of the *average* or *moderate yielding strains..*

(c) A *very small percentage* of the *inferior* or *low yielding strains* limited to the occasional tuber that would grade up to the required size and form.

Upon the other hand what would be the character of the seed stock used by the grower who insists upon selling the marketable tubers and retaining the small ones for planting? His choice would include:

(a) A *very insignificant percentage* of the *superior* or *high yielding strains.*

(b) A *small percentage* of the *moderate yielding strains.*

(c) A *very heavy, almost total percentage* of the *low yielding* or *inferior strains.*

The persistent use of small seed year after year can have but one result, the rapid deterioration of the variety thus perpetuated by the steady, certain process of elimination of all the good and superior strains of that variety. Growers who practice this plan of "seed saving" and dollar saving(?) are persistent in their theory that varieties of potatoes "run out;" and they offer their personal experience and their crops in support of their theory and as evidence that they are right in their conclusions.

There are, however, certain conditions under which, for a time at least, the smaller tubers (not culls) may be used with good results. It is subsequent to a thorough course of selection in which there has been a "weeding out" of the inferior strains. A tuber may be small because of crowding in the hill with larger tubers; or it may be small because of some unfavorable condition under which it was forced to exist; these, if they be of selected strains, ought to give satisfactory results when used for seed. It is the small tuber that is small because of *inherent inferiority* to which objection may be justly urged. However, at the same time of using these smaller tubers for seed there should be in progress a continuity of seed selection with the purpose in view of gradual, constant improvement of the variety or varieties which have been accepted as the most

profitable for local or special requirements. The land owner who insists upon placing the cream of his farm crops upon the market and using the "skim-milk" product for the basis of succeeding crops is progressing only toward well merited defeat which will be met sooner or later. The choicest of the crop is none too good for seed purposes.

PLANTING AND CULTURE

In a preceding chapter have been discussed approved methods of preparation and fertilization of the soil for potatoes. Thorough preparation renders planting a comparatively easy and agreeable task—especially where the land is level, or nearly so, and a modern horse-power planter is used. For the general crop the rows should be spaced three feet apart and the seed pieces dropped from 14 to 16 inches in the rows. The more dwarf growing plants of some of the first early sorts may allow of spacing the rows at 30 inches and dropping the seed pieces 12 inches apart, though this close planting is not recommended for the stronger growing varieties. The machine should be adjusted to deposit the seed pieces at least four inches below the level of the surface of the ground. Most planters cover the seed in such a way as to leave a little ridge over the rows, beneath which the seed pieces are probably covered something near six inches in depth. After the seed has sprouted well and the young shoots are approaching the surface of the ground, the field may be gone over with a weeder or a fine smoothing harrow in which the teeth slant backward, levelling the ridges and leaving the surface smooth, even and mellow. A second and even third cultivation may be given with weeder or harrow by the time the little plants are beginning to show well in the rows. These early cultivations save much work later on, as millions of weed seeds are germinated and the tiny plants are killed before they have become established.

On rough, steep ground or on small areas where a horse planter is not practicable, the ground may be furrowed with a large-bladed, single-shovel plow, as described in a foregoing chapter. The furrows should be deep and broad even if it should require two or three passages with the shovel plow to complete them. The rows should always be across the slope of the hill—never up and down the slopes where it is possible to avoid it. By holding the plow firmly the loose soil will be thrown out on either side—a part of it rolling back into the forrow as the shovel of the plow passes, leaving three or four inches of loose soil in the bottom of the furrow upon which to drop the seed pieces. The fertilizer, as before stated, should be applied over the bottom and sides of the broad furrow before dropping the seed, where hand work is done. The rows are spaced and the seed pieces dropped the same distances apart as when planting with a machine.

The seed may be covered either with a hand hoe or shovel plow. If the ground be not too full of stones or sods or roots, the plow will do very good work when run on either side of the open furrow at the proper distance to fill it with mellow soil. The plot should be run over with a weeder or fine tooth harrow when weed seeds begin to germinate, as described for a machine planted field.

The after cultivation is done with a narrow-hoed or "spike-toothed" cultivator, keeping the surface of the ground as level as possible, mellow and free from weeds throughout the growing season. The crust of the soil, after rains, should be broken up as soon as the ground is dry enough to work, and a fine "soil-mulch" maintained on the surface as long as it is possible to drive between the rows with the cultivator without pulling out or breaking the tops of the plants. The maintenance of the "dust mulch" is a sort of insurance against the effects of dry weather; and fine crops of potatoes have been grown by this careful, persistent cultural work even in seasons of serious drought.

The old plan of "hilling up" the rows of potatoes, leaving a high, sharp ridge, is quite unnecessary, and, in fact, is detrimental to the success of the crop should the latter part of the season be deficient in rainfall. Sufficient soil should be worked toward the rows with the cultivator, to insure that the new tubers may not be exposed to the sun; but the surface of the soil should be kept practically level the season through so that the entire area may uniformly receive, absorb and retain the rainfall.

SPRAYING FOR INSECTS AND FUNGOUS DISEASES

The spraying outfit is coming to be regarded as an important factor in the equipment of the potato grower. There are many excellent sprayers made; in fact so many firms are engaged in making spraying machines—there is so much competition—that a sprayer necessarily must come up to a reasonable standard of efficiency in order to be recognized on the market. For small plots of potatoes for family use, as well for general use about small grounds and the kitchen garden, there is no form of sprayer more convenient, effective and satisfactory than the small, compressed-air outfit. This consists of a strong, air-tight tank, preferably constructed of heavy, sheet brass, fitted with an air-pump for compressing the air. These tanks are about four gallons in capacity. In use three gallons of spray mixture are filled in the tank and the remaining space of one gallon pumped full of air to a high pressure. The compressed air forces the liquid out through the nozzle in a fine mist. As the pressure becomes too low for effective work through continued spraying, a few strokes of the air-pump again fills the vacant space in the tank

with compressed air. Two or three short pumpings will suffice to force out the contents of the tank. Such outfits are easily carried about with a strap over the shoulder, while the addition of a few feet of light, brass extension pipe, connected to the hose, enables the operator to spray a limited number of young fruit or ornamental trees of considerable height.

For field use in potato spraying, a horse power outfit will be necessary. These, of various styles, are constructed to spray from four to six rows at a single passage, making rapid work in combating the insect and fungus enemies of the potato plant. The traction geared potato sprayers are preferable to those fitted merely with hand pumps, as one man to drive the team is all that is required in the field. However, excellent four-row sprayers can be made by any one who has a good, barrel spray pump and is handy with plumbers' tools. Such a barrel outfit may be placed in a wagon or cart and carried through the field, employing one man to drive and another to pump.

The nozzles on potato sprayers should be adjustable to different widths of rows, and only such nozzles should be used as will apply the liquid with considerable force directly downward upon the plant and in a fine mist or fog-like spray. Mere sprinkling will not suffice where fungus disease is to be effectually combated.

Spraying should begin on the early varieties as soon as the plants are from 6 to 8 inches in height, using a combined mixture that is both a fungicide and an insecticide. Early blight and Colorado beetles are thereby combated at the same time. Spraying should be repeated every ten days or two weeks.

The later varieties or "general crop" may likewise be protected, special care being given to spraying with Bordeaux mixture for the late blight during the month of July. The insecticides may readily be combined with the Bordeaux mixture (fungicide) when the presence of the larvae of the Colorado beetles render an insecticide necessary. The black or "blister beetles," so destructive in certain sections and so difficult to effectually combat with poisons, become sadly discouraged where Bordeaux mixture is freely used and leave the potato field if there be other vegetation in the vicinity upon which they may subsist. The formula for making Bordeaux mixture is given below:

BORDEAUX MIXTURE

Copper sulfate (blue vitriol)	4 pounds
Fresh lime	5 pounds
Water	50 gallons

Where Bordeaux mixture is needed for different sprayings during the season much time and inconvenience may be saved by making up a "stock solution" of copper sulphate; this stock solution will keep indefinitely without deterioration. To make the stock solution use a good barrel (a kerosene, vinegar or whiskey barrel serves well). After removing one of the heads fill the barrel to within 6 or 8 inches of the top with water, measuring the water by gallons. Weigh out in a burlap bag, as many pounds of copper sulphate as the number of gallons of water contained in the barrel. Tie the bag with a strong twine close down to the contents, leaving a loop through which a stick may be thrust. Suspend the bag of copper sulphate in the water by resting the stick across the top of the barrel, in such a way that the bag will be but partially submerged in the water. The material will dissolve much more quickly when held near the surface of the water than when poured loosely into the barrel or suspended near its bottom, as the copper charged water is heavier than the clear water and sinks to the bottom in the form of a saturated solution which no longer has the power to dissolve the substance with which it is laden. When the content of the bag is dissolved each gallon of the water in the barrel will contain one pound of copper sulphate. It is well to slightly stir or agitate the solution previous to measuring out a portion for use.

Bordeaux mixture: Pour four gallons of the stock solution (4 pounds copper sulphate) into the spray barrel and add water to this until the barrel is half filled. The copper solution must be weakened thus before adding the lime or a curdled mixture will result. Weight out, in a bucket, 5 pounds of fresh hydrated lime (known also as "builders' lime," "flour lime," "sack lime," etc.). Add water to the lime, stirring vigorously and pouring off the "milk of lime" or thin white-wash into a second vessel until all the lime is dissolved. Strain the milk of lime, diluted still further with water, through a fine meshed brass wire strainer into the dilute copper solution in the spray barrel, churning vigorously as the lime is being added. A clear bright blue mixture should result. Add to this mixture whatever poison it be desired to use for the destruction of insects and finish by filling the barrel with water.

INSECTICIDES

Arsenate of lead: This is a commercial preparation, as generally used, and one of the most lasting and effective known at the present time, as it is very adhesive. It comes to the buyer in paste form in different sized cans, buckets, kegs or barrels. For one barrel or 50 gallons of spray mixture weigh out, in a bucket, 3 pounds of

arsenate of lead. Add a little water and stir and beat vigorously until a quantity of "milk of lead" is formed. Pour this off into a second vessel or through the strainer into the spray barrel as the paste is dissolved. The lead is slow to dissolve, but by repeatedly adding water, stirring and pouring off it will soon be reduced to milk of lead. Arsenate of lead will not injure foliage, even if used without lime.

ARSENITE OF SODA

Commercial white arsenic	2 pounds
Carbonate of soda	4 pounds

Boil the arsenic and carbonate of soda together in one gallon of water until a clear liquid is formed (15 minutes of brisk boiling will usually suffice). Dilute this solution to 2 gallons by adding water. Pour into a two gallon jug or other vessel that may be securely covered and label "Poison." Use one quart of this stock solution to 50 gallons of spray mixture. If not used in Bordeaux mixture add 5 pounds of lime to insure against burning of foliage.

PARIS GREEN

Paris green	8 ounces
Water	50 gallons

Paris green may be used in the Bordeaux mixture without danger of injury to foliage. If used without combining with Bordeaux add 5 pounds of lime to the barrel of solution.

Lime for spraying purposes: A word should be added regarding the kinds of lime recommended for spray mixtures, as much confusion and misunderstanding exist among beginners in spraying. Fresh burned, lump lime or "stone lime" cannot be excelled for spraying purposes, but many times and in many places cannot be obtained in the desired state of freshness; hence the hydrated or sack lime has come into quite general use. Stone lime, too, requires slaking, and unless a considerable quantity be slaked at a time and this held in reserve as a "stock supply," several purchases as well as several slakings will need to be made during the spraying season. It is always best to buy a quantity at the first of the season, slake it all at once and preserve it in paste form for use. In order to prepare for spraying in this way, weigh out say 50 pounds of good, sound lumps. Slake these in a shallow box by adding water and stirring well to prevent burning. Continue to add water and stir until a smooth paste is formed. Level this paste down in the box and when it is well settled mark the surface off into ten squares of uniform size. Each square will contain what was formerly 5 pounds of lump lime. Cut out and use one square for each 50 gallon barrel of spray mixture. Keep the paste at all times covered with water to prevent drying out.

Hydrated or builders' lime can usually be purchased of most dealers in lumber or building materials. It is put up in air-tight sacks and will keep in good condition a long lime if kept in a dry place. This is a very convenient form of lime for the sprayer, as no slaking is necessary. However, it is well to use a little excess in weight over that recommended for the stone lime, therefore 6 pounds of hydrated lime is used for each barrel of 50 gallons of Bordeaux mixture. The writer has used only the hydrated for the past six years with quite satisfactory results.

A PRACTICAL CLASSIFICATION OR GROUPING OF VARIETIES OF POTATOES

The Ohio Experiment Station has tested hundreds of varieties of potatoes and is yet continuing this work. Reports of these tests may be obtained by application, free of cost. Many new varieties are constantly being offered by originators, introducers or dealers, in different parts of the country. A few of these prove of value; an occasional one is excellent; many are quite inferior to our already well known and standard kinds. It is not the purpose of the writer to embody a descriptive list of varieties in this cultural treatise.

Fig. 12. Variety test of potatoes.

Such a chapter would need revision many times over before the chapters dealing with cultural methods should lose their value through evolution or modification of approved and dependable methods of the present day. The question of varieties, too, is one that cannot be treated in a general way with equal benefit to all potato growers. Each grower must determine for himself those varieties which do best under his particular conditions of soil and climate, and use his own judgment in retaining the choicest of these for home use or

market, or both. It is advisable, however, for each grower to test the more promising of the newer kinds grown and reported upon by the experiment station of his state. He may thus find one or more varieties which would prove to be more profitable or excellent in quality than the kinds he has been growing for market or table use. The writer has visited certain sections of Ohio in which the same variety has been grown for perhaps ten, fifteen or twenty years, and this without any particular care in selection and improvement of seed stock. The newer varieties of superior value are unknown—perhaps unheard of.

It has been remarked by certain growers, too, that it is well nigh useless to buy new varieties; for, in many cases, they declare, the alleged new variety proves to be only an old sort renamed and sold at a fancy price. This position tends to confusion and misunderstanding and often unjust criticism of originator, introducers and dealers in pure seed stock. True there are cases in which old varieties may have been reintroduced under new names—we are aware of a limited number of such cases—but such deception is more rare than general. Usually the confusion of growers is occasioned by the fact that there are several distinct types, families or groups of potatoes and that the hundreds of varieties of different origin may be classified in these several groups. Indeed there are many varieties of separate and distinct origin which follow a single type so closely as not to be readily distinguished from each other either by habit of growth of plant or character of tubers, even by an expert potato specialist.

To present in completeness and with absolute accuracy the lists of varieties belonging to the various groups would tax the most careful student of botany. Such exact classification is neither necessary nor advisable in a purely practical treatise of this kind. In the following classification the writer has not only reduced the groups to the least possible number, but mentions only a few of the many varieties which might easily be included in each one. The classification is based principally upon similarity of the character of the tubers of the different varieties, without special consideration of the similarity of the plants of each. In many cases, however, there is a similarity of plants as well as of tubers.

The Triumph Group: round, white, red or mottled; first early.

Bliss Red Triumph (known also as Stray Beauty, Strawberry and Bermuda red.

Bliss White Triumph	Noroton Beauty	Nott's Early Peachblow
	Woods' Earliest	

The Early Market Group: Round or oval, flattened; white or slightly tinted; very early; good quality—much superior to the Triumph group.

Early Market   Early Standard   Early Petosky   Irish Cobbler

Early Ohio Group: very similar to Early Ohio in various ways.

Early Ohio   Early White Ohio   Early Six Weeks
Baker's Extra Early   Peck's Early   Acme   Ohio Junior

Early Rose Group: long or oblong, cylindrical or flattened; pink or white or mottled.

Early Rose   Early Roser   Mountrose   Northern Star
Early Fortune   Early Bovee   Early Sensation
Early Norther   Algoma   Miller-Brooke   Early Breakfast (white)
Early Michigan (white)

Green Mountain Group: oblong to long; somewhat irregular in form; usually white or straw color.

Green Mountain   Whiton's White Mammoth   Gold Coin
Ionia   Uncle Sam   Washington   Happy Medium
American Giant   State of Maine

Seneca Beauty Group: long or oblong, smooth; small, very shallow eyes; red, pink, or white with pink eyes; quality excellent.

Seneca Beauty   Livingston (White Seneca Beauty)   Piqua Chief
Pat's Choice

Rural New Yorker Group: round or oval, much flattened; few shallow eyes; color usually white; quality variable.

Rural New Yorker   Rural Russet   Banner   Carman No. 3
President Roosevelt   Prosperity   Sir Walter Raleigh
Ohio Wonder   Green's No. 21   White Giant   World Wonder

SEASONAL REPORT ON POTATOES, 1909

By JOS. H. GOURLEY

An interesting and instructive feature of the season's work for 1909 was a further study of the results of sprouting potatoes in sunlight before planting.

The results given in the table below show that it is better to take extra pains to drop the pieces in the furrow sprout end up. The first row was dropped with the sprouts up in each case, the second row with the sprouts down, and the third at random, irrespective of the position of the sprouts. The second series is a duplication of the first.

PERCENTAGE OF GERMINATION

	Sprouts Up	Sprouts Down	At Random
First series	98%	66%	68%
Second series	89%	76%	89%
Average	93%	71%	78%

These results indicate that considerable care is necessary in planting sun-sprouted potatoes, and that if dropped by a planter the work is not likely to be done satisfactorily.

LATE GROWN VS. COMMON SEED POTATOES

Stock which had been raised from sun-sprouted seed, planted in July, 1908, was planted in the fertilizer plots the past year (1909) by the side of common stock, or seed which had been grown in the ordinary way. There are 34 tenth-acre plots in each series of the 3-year rotation, potatoes-wheat-clover. The plots are 272 feet long and 16 feet wide, which permits five rows of potatoes in each plot. The first three rows in each plot were planted with seed tubers from the July planted stock and the other two with the ordinary seed. This method precluded the possibility of any unequal effect upon the various plots by using two lots of seed.

LATE GROWN VS. COMMON POTATO SEED

Rows 272 feet long, hills 15 inches apart, 216 hills per row.

Plot No.	No. of hills per row		Percent of germination		Average yield per row—lbs.	
	Late grown Rows 1, 2, 3	Common Rows 4, 5	Late grown Rows 1, 2, 3	Common Rows 4, 5	Late grown Rows 1, 2, 3	Common Rows 4, 5
1	159	148.5	73	68	74.1	49
2	157	168.5	72	78	46	47.5
3	178.7	159.5	82	73	89	49.5
4	188	163	87	75	74	27.5
5	200.3	171.5	92	79	73.1	52.7
6	199.6	169	92	78	69.8	58.5
7	204	178	94	82	44	21
8	205	175	94	81	112	89
9	205	173.5	94	80	119	73.7
10	196	166.5	90	77	59.1	23
11	213	178.5	98	82	109.5	82.5
12	204.6	199	94	92	116	86.5
13	205	171.5	94	79	36.1	31.2
14	199.3	197.5	92	91	135.1	112.7
15	203.3	178	94	82	126.1	97.7
16	196.6	179.5	91	83	31.1	43.2
17	195.3	173	90	80	78.8	61.5
18	190.6	178	88	82	75.6	54.2
19	198.6	180	92	83	56	47
20	205.3	192.5	94	89	115.1	83
21	201.3	170	93	78	85	70
22	177.3	159.5	82	73	61	31
23	206.6	170	95	78	110.8	76.7
24	196.6	179	91	82	101	98.7
25	192	162.5	89	75	53.8	45
26	189.6	179	87	82	111.1	89.5
27	193.6	175	89	81	114.1	86.2
28	189	166	87	76	64	63
29	200.3	172.5	92	79	126	93.7
30	204	175	94	81	136.5	96.2
31	196.6	155.5	91	71	43	40.2
32	209	185	96	85	154.8	98.5
33	197.3	165.5	91	76	88.6	85.5
34	186.3	143.5	86	66	49.1	33.8
Tota Ave.	195.4	172.3	90	79.3	86.4	64.6

The potatoes were all the same variety (Carman No. 3) and were all planted the same day. The plants grown from July sun-sprouted seed appeared nearly two weeks in advance of the others and maintained quite a noticable difference until they were of large size. In fact so noticeable was the difference in the vigor and increased size of the plants that the casual observer would stop and remark and the more interested one would inquire into the details of the method. Many thought that the two parts of the plots were planted at different dates or possibly were of different varieties. Let it be understood that this particular seed was not sprouted but that it was the crop raised from sprouted seed, which had been planted the first of July the year previous. The serious inroads made by the dry rot fungus or fusarium wilt seriously impaired the results, but an examination of the figures given in the table show that the increased yield and higher percent of germination were constant throughout the plots.

A half bushel of potatoes raised from sprouted seed were placed in a closed box in the storage room beside a half bushel raised by the ordinary method placed in a similar closed box. A half bushel

of the same were placed in closed boxes and set in the greenhouse under a raised bed,over winter. In both cases the July planted potatoes kept much firmer and were much slower to sprout than the others.

TREATING POTAOTES FOR SCAB

There are several methods of treating potatoes for scab, such as with flowers of sulphur, soaking in formalin solution or corrosive sublimate, and fumigating with formalin gas. The later method is not used as extensively as it should be, probably because the average grower is not acquainted with it. A comparative test was made between soaking in formalin and the formalin gas treatment.

Johnson No. 1 was used in the test, for the reason that it was the most infected variety available. The tubers were nearly covered with scab and as a consequence the treated plots showed far more scab than would be the case if fairly clean seed were used.

The two methods consist essentially in the following details:

Soaking in Formalin: One pint formalin to 15 gallons of water, soak 2 hours. The seed is thrown into a tub containing this solution or placed in wire baskets and suspended in barrels containing the solution. They are then dried and are ready to plant.

Fumigating with Formalin Gas: Three pints of formalin is poured over 23 ounces of potassium permanganate (for each 1000 cubic feet of space) and the potatoes are exposed to the fumes for 24 to 48 hours.

An air-tight room or enclosure is necessary, with all cracks carefully filled in with paper or other material, as the gas is quite penetrating. A large pan or earthen vessel should be used as there is large increase in volume through the chemical action when the formalin comes in contact with the permanganate. The person should leave the room immediately, as the gas is very poisonous.*

The following results were obtained by the two methods:

Treatment of Seed	Percent Scabby Potatoes in Crop		
	Row 1	Row 2	Average
Untreated	50.8	66.3	58.5
Soaked in formalin	10.8	22,6	16.7
Fumigated	21.0	15.9	18.4

When there is a quantity of potatoes to be treated it would be advisable to use the fumigation method as the figures show practically no difference in the two methods and fumigation requires no

* Formalin can be purchased for 25 cents per pound. Potassium permanganate at 25 to 30 cents per pound.

time or labor on the part of the operator aside from preparing the room or cellar for the work. On the other hand, if there are but few potatoes to be planted the soaking method will probably be more feasible and satisfactory.

EFFECT OF TREATMENT ON VITALITY OF THE SEED

Unfavorable results are sometimes reported from treating seed potatoes for the scab fungus. Recognizing that injury may sometimes result from this practice, but believing it to be the fault of the operator in most cases, the following observations were made during the past season. The rows were 40 rods long and 3 feet apart. Planted April 28th. All treatment refers to soaking in formalin.

Effect of treatment on vitality of the seed:

3 rows Early Toledo Market	Treated
4 rows " " "	Untreated
3 rows Early Bird	Treated
3 rows " "	Untreated
1 row Miller-Brooke	Treated
1 row " "	Untreated
3 rows W. W. Mammoth	Treated
3 rows " "	Untreated
4 rows Pres. Roosevelt	Treated
3 rows " "	Untreated
2 rows Gold Coin	Treated
3 rows " "	Untreated

Careful observations were made from the time of germination throughout the season to maturity and in no case was there any appreciable difference in date of germination, percentage of germination or vigor of plants, between the treated and untreated seed throughout the test.

Cases are reported where germination was poor or slow or an apparent lack of vigor in the plants because of treatment but in all cases which we have been able to trace the treatment was longer or the solution stronger than recommended, or there was improper handling of the seed after treatment.

RESULTS FROM THE USE OF FERTILIZERS ON POTATOES

In this experiment potatoes, wheat and clover are grown in a 3-year rotation, each crop being grown every season. The fertilizers are applied to both potatoes and wheat. The table gives the results as computed on the potato crop alone, but the wheat and clover show a further increase, which adds to the total and net profits from the treatment.

INCREASE PER ACRE SECURED FROM THE USE OF FERTILIZERS ON POTATOES, 15 YEAR AVERAGES. YIELD OF UNFERTILIZED PLOTS, 154 BUSHELS PER ACRE

Fertilizing materials and quantities used per acre	Increase per acre bus.	Cost of fertilizers per acre	Value of increase per acre at 40c. per bushel	Net profit per acre	Cost of increase per bushel
160 lbs. acid phosphate	14.99	$1.20	$5.99	$4.79	$.08
100 lbs. muriate potash	9.52	2.50	3.80	1.30	.26
80 lbs. nitrate of soda	9.08	2.00	3.63	1.63	.22
160 lbs. acid phosphate 80 lbs. nitrate of soda	20.79	3.20	8.31	5.11	.15
160 lbs. acid phosphate 100 lbs. muriate potash	30.66	3.70	12.26	8.56	.12
100 lbs. muriate potash 80 lbs. nitrate soda	12.36	4.50	4.94	.44	.36
160 lbs. acid phosphate 100 lbs. muriate potash 80 lbs. nitrate soda	24.18	5.70	9.67	3.97	.23
160 lbs. acid phosphate 100 lbs. muriate potash 160 lbs. nitrate soda	31.71	7.70	12.68	4.98	.24
320 lbs. acid phosphate 200 lbs. muriate potash 160 lbs. nitrate soda	35.91	11.40	14.36	2.96	.31
480 lbs. acid phosphate 300 lbs. muriate potash 320 lbs. nitrate soda	35.63	19.10	14.25	8.56	.53
160 lbs. acid phosphate 100 lbs. muriate potash 80 lbs nitrate soda	42.26	5.70	16.90	11.20	.13
8 tons yard manure	39.31		15.72		

It will be seen that the lowest cost of the increase has been in the use of acid phosphate alone, but this should not obscure the fact that the greatest profit per acre has been secured with a complete fertilizer, and this, notwithstanding the fact that this land is of higher than average fertility—the unfertilized yield of wheat having averaged 26 bushels per acre for the fifteen years—and that clover has been grown every third season.

AN OUTBREAK OF FUSARIUM WILT

Early in the season a pronounced condition of tip burn was noticed both throughout the Carmans in the fertilizer work and in the variety test grounds. Soon correspondence began to show that it was prevalent throughout the state, causing serious loss. There was some early blight accompanying the tip burn but no late blight developed at the Station. The condition grew much worse as the season advanced; the foliage assumed a pronounced yellowing, and the disease was identified by the Botanical department of the Station as *Fusarium oxysporum* Schlecht. or dry rot fungus. Many varieties died in July and August and nearly all varieties died prematurely

The general manifestations of the disease are a check in growth, usually a curling and folding of the leaves, most noticeable at the growing point of the haulm, a decided condition of tipburn on practically all the leaves of the plant, a premature dying of the plant and finally a darkening of the tissue of the tuber at the stem end. It begins by yellowing the woody vessels at the stem of the tuber but finally may work through the whole tissue.

The premature dying of the plant greatly affects the yield and size of tubers. In some places where the disease had an early development the crop was scarcely worth digging.

There is some variation in the susceptibility of varieties but nearly all the standard early and late varieties were attacked to a greater or less degree in the Station test grounds.

This disease is very slightly controlled by spraying except as it promotes a healthier condition of the plant.

In the fertilizer plots the one receiving the largest amount of fertilizers remained green the longest, while the "No fertilizer" plots were very noticeably the first to go down. They were all sprayed and cultivated alike.

The selection of disease resistant varieties and the special selection of resistant plants, combined with an intelligent rotation of crops and proper handling of seed will be factors largely instrumental in fighting the disease. The Station has made numerous tests for resistance to this disease.

The comparative effect of the Fusarium trouble on different varieties on August 6th is shown below. Later practically all varieties succumbed to the disease.

CONDITION OF VINES AUGUST 6, 1909

DEAD

Early Petosky*	Early Standard*	Epicure
Early Russet*	Noroton Beauty	

BADLY AFFECTED

Cal. Russet*	Early Thoroughbred*	Merrill*
Clyde*	Frayer O. K.*	Millerbrooke*
Early Fortune	Happy Medium*	White Albion*
Early Johnson*	Knowles' Big Crop*	Plucky Baltimore*
Early Ohio*	Lily White*	White Rose
	May's Late*	

FAIRLY GREEN

Bovee*	Late Hebron	Red Pearle*
Early Bird*	Market Prize*	Noxall
Early Breakfast*	Early Monarch	Norcross*
Early Michigan*	Early Fortune	Kellers Green Mt.
Green Mt.*	White Rose*	New Snow
Ionia Seedling*	Washington*	Pioneer
Johnson's No. 2*	Seedling No. 4	Seedling No. 4
	Rural New Yorker*	

GREEN

Carman*	D. J. Miller*	Prosperity*
S. Com. Violet*	N. Late Nebraska*	Pres. Roosevelt*
Mortgage Lifter*	New Queen*	Planet*
Green's 21*	Banner*	Pioneer
Harrolds' Choice*	White Elephant*	Ohio Wonder*
Johnson's No. 1*	Snow*	New Snow
Late Petosky*	Seneca Beauty*	Late Hebron
Lepas*	Seedling No. 5*	Noxall
Livingston*	Seedling No. 4*	Snowflake
Early Manistee*	Rural Russet*	W. W. Mammoth

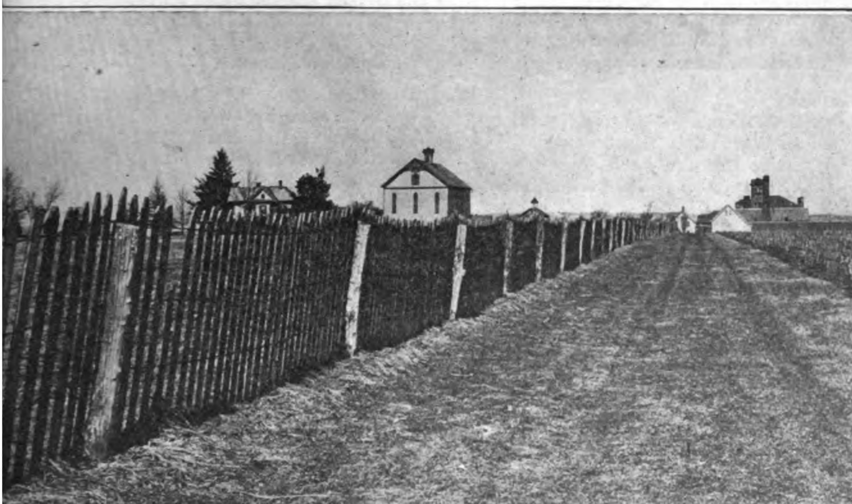
* Means that duplicate row was the same.

THE RELATIVE DURABILITY OF POST TIMBERS

OHIO Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., JUNE, 1910

BULLETIN 219



Section of a fence on the farm at the Ohio Agricultural Experiment Station

The Bulletins of this Station are sent free to all residents of the State who request them. When a change of address is desired, both the old and the new address should be given. All correspondence should be addressed to EXPERIMENT STATION, Wooster, Ohio.

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SIR:—I have the honor to transmit herewith and to recommend for publication as a bulletin of the Station the accompanying manuscript entitled "The Relative Durability of Post Timbers."

This bulletin, prepared by J. J. Crumley, assistant in forestry, during the period when the work was under my charge, is the result of extended investigations in this and other states regarding the relative durability of the kinds of timber most commonly used for posts. One object in going into other states in this work was to get data on some varieties of timber that have not been in use long in this state but are rapidly coming into general use and are very important in this investigation.

So far as known no work of this kind has ever been undertaken on so large a scale. While this fact alone is not urged as a reason for drawing definite conclusions, it may be taken as evidence to establish with considerable certainty the relative durability of the kinds of timber named in the investigations.

The striking variability of wood as to durability under varying conditions makes it plain that the number of observations count for a great deal. On the whole, the results cannot fail to be of value, both as to the facts stated, and suggestions which may be aroused in the minds of readers.

Respectfully,

W. J. GREEN, *Consulting Forester.*

CHAS. E. THORNE, *Director.*

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 219 JUNE, 1910

THE RELATIVE DURABILITY OF POST TIMBERS

BY J. J. CRUMLEY

The various state Experiment Stations and the Forest Service at Washington are continually receiving inquiries concerning the durability of timbers in the soil. The farm journals throughout the country are also frequently called upon to answer questions on this subject.

In the forestry exhibit at the Ohio State Fair, in 1906, and also in 1909, there was a group of eight specimens of wood labeled "Post Timbers." During the time that these specimens were on exhibition there were six different varieties of wood pointed out with the expression "That is the best for posts." These six were yellow locust, red cedar, hardy catalpa, Osage orange, mulberry and chestnut.

While the data published herein were being collected, men were found living on adjacent farms—one believing very steadfastly that posts should be seasoned before they are put in the ground, the other just as firm in his belief that they should be set green; and again, one believing that posts should be set with the top or

small end in the ground, that is, the opposite to the way they grew in the tree, the other that they should be set with the top or small end up. These men were probably speaking from an experience of many years. Such circumstances may be duplicated over and over. The above and scores of other observations of this kind seem to indicate that there is need of careful and extended investigation along this line.

The time has come when we must make a clear distinction between the qualities of post timbers. Timber is getting more and more scarce and prices keep increasing, and the future purchaser must know what he is buying. Hundreds of farmers in our state are beginning to set out trees. More of them are planting with a view to growing posts than for any other purpose. Surely then we should understand as clearly as possible which timber will produce the most durable post. We should also consider carefully the rate of growth, pests, and adaptability to soil, climate, etc.

The material published in this bulletin has been obtained from the examination of 292 fences containing 30,160 posts. These fences are situated in Ohio, Indiana, Illinois, Kansas and Texas. The counties in Ohio in which fences have been examined are: Warren, Greene, Clark, Guernsey, Adams, Ross, Wayne, Fulton, Montgomery, Champaign, Morrow, Knox, Van Wert, Preble, Williams, Putnam, Union, Miami and Franklin.

The object in going outside of the state was to get data on two kinds of timber, the hardy catalpa and the Osage orange, that have not been used very long in this state, but are very important in the consideration of post timbers. Two summers were spent in the Wabash Valley, the home of the hardy catalpa. Here posts were studied that were cut from trees that grew in the forest. A portion of one summer was spent in Kansas, examining catalpa posts cut from trees that grew in cultivated groves in the Farlington, Hunnewell and Munger plantations. A portion of one summer was spent in Texas, examining Osage orange posts.

In each of these states a few fences of oak, locust and mulberry were examined for sake of comparison, to use as a kind of measuring stick in case the soils or climate might prove more or less severe on posts than in Ohio.

The manner of collecting this material was as follows: A fence of considerable age having been found, usually old enough to contain rotten posts, it was examined closely, the data being taken down on a blank form. One of these forms is given below, filled out.

TABLE I

OHIO AGRICULTURAL EXPERIMENT STATION

DATA CONCERNING FENCE POSTS

November 25, 1906.

Owner Edwin Woods **P. O.** Lebanon, Ohio

County Warren **Township** Union

Location 3¼ miles southeast of town. Fence is the east and north sides of the "spring field."

Kind of Fence Board and wire.

Direction N-S and E-W.

Soil Clay loam, rather thin.

Drainage Good.

Kind of Posts Yellow locusts.

Age 20½ years. Set in spring of 1886.

Time of Cutting

Seasoning Seasoned.

Size of Posts Small to medium.

Distance Apart 8 feet.

Number Sound 126 (81 percent) u s 71 (82½ percent) d s 26 (66⅔ percent)

Number Rotten 30 (19 percent) u r 15 d r 13

Total Number 156 86 39

Remarks: In case of 31 of the posts it was not evident whether they were set top up or top down.

Posts came from Kentucky. Were made from large trees. Flat bark posts and triangular heart posts are frequent. Posts next to bark show better record than the triangular ones split from center of tree.

These are from same lot of posts as those on the W. and S. side of same field (recorded in Loc. No. 9, 46). which were set one year earlier and have a larger percent of sound posts. Size and selection caused the difference.

The most of these items are taken from the fence itself and its surroundings. "Time of Cutting" and "Seasoning" can not always be obtained. The "Age" is especially important and was in each case obtained with the utmost care.

When the above items were obtained, the fence was then examined post by post and the condition of each was set down in order as indicated in the following table.

TABLE II

OHIO AGRICULTURAL EXPERIMENT STATION

POST TO POST RECORD

(u)—set top up. (d)—set top down. (s)—sound. (f)—fair. (p)—poor. (r)—rotten. (h)—heart post. (b)—post next to bark. In summary, (f) is classed with (s) and (p) with (r).

Owner Edwin Wood

Beginning at S. E. cor. of field, go north.

1	d s	d s	u s	u s	s	s
2	s	d r	u s	u s	u s	d s
3	s	u s	u s	u s	s	d r
4	u s	u r	u s	u r	d s	u s
5	u s	d r	u s	u p	u s	d p
6	s	s	u s	d f	u s	u s
7	u f	p	d s	d s	u f	d f
8	u s	u s	u s	u f	u s	Cor. N. W.
9	u s	s	u s	d f	s	
10	u s	u s	u s	u r	u r	
11	u s	u s	u s +	u s	d s	d s 26
12	u s	u s	o s	u s	d r	d r 13
13	s	u s	d s	s	d f	39
14	u s	u s	u f	u s	u s	
15	d s	r	s	u r	u s	u s 71
16	u s	d r	d s	u r	u s	u r 15
17	d s	u s	u r	u p	d s	86
18	u s	d s	u s	d r	d r	
19	u r	u s	s	d s	u s	
20	s	d s	u s	u f	u s	
21	u s	u s	s	u p	d r	
22	s	s	u s	u r	d r	
23	s	u f	u s	s	d f	
24	s	u f	d s	u s	u s	
25	f	d p	d s	u s	s	
26	s	d s	s	d s	u r	
27	u s	u s	u s	s	d p	
28	s	u s	u r	s	u s	
29	s	d f	u f	s	d r	
30	u s	u s	u s	d s	u r	

+—N. E. Cor.

In this table, each column contains the record of 30 posts. That is, the one at the head of the second column is the thirty-first post in the fence, the one at the head of the third column is the sixty-first, etc. The whole fence contains 157 posts, one of which, No. 72, is oak, leaving 156 locusts to be counted in the summary.

One interesting item that this fence furnishes is the relative condition of posts set with the top down and those set with the top up. Of those set top down, there are just half as many rotten as

there are sound; of those set top up, there are only about one-fifth as many rotten as there are sound. Sometimes a post does not show in which position it has been set. There are 31 of such in this fence.

It will be noticed under "Remarks," Table I, that this fence has a number of triangular heart posts and a similar number of thin, flat posts that have the heart split off. The most of the rotten posts in the fence are found among the heart posts and nearly all of the thin, flat ones are sound. The same feature was found in many other fences, and is true of several kinds of timber.

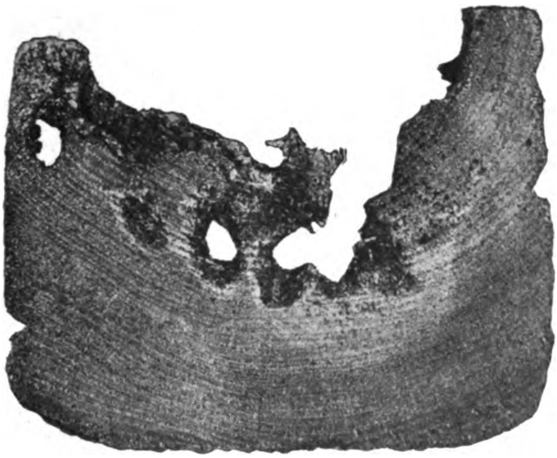

Fig. 1

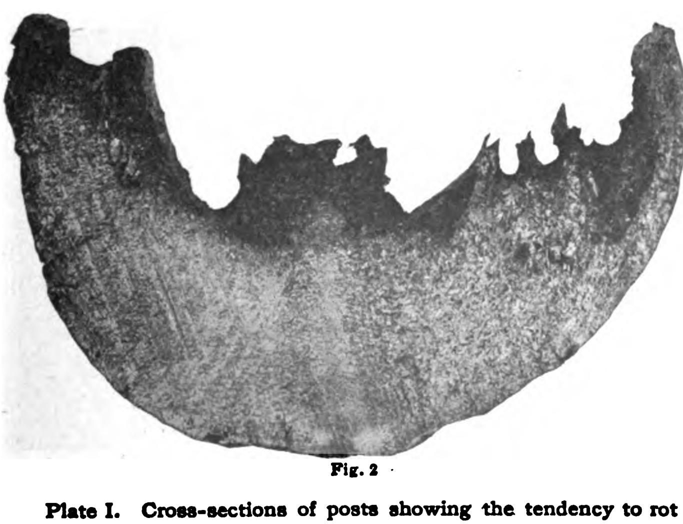

Fig. 2

Plate I. Cross-sections of posts showing the tendency to rot at the heart first. Fig. 1 is catalpa. Fig. 2 is white cedar.

Plate II. Longitudinal section of a locust post showing tendency to rot at heart first. See pages 613, 614, 622, 625.

The data in detail of one more fence are given below on account of some individual items and for reference later.

TABLE III

OHIO AGRICULTURAL EXPERIMENT STATION

DATA CONCERNING FENCE POSTS

November, 1907.

Owner John Hyde P. O. Yellow Springs, Ohio.

County Greene Township Miami

Location One mile S. of town on W. side of woods, on Xenia pike.

Kind of Fence Picket

Direction N-S.

Soil Clay-loam, limestone.

Drainage Good.

Kind of Posts White oak.

Age 13½ years; set in spring of 1894.

Time of Cutting Winter.

Seasoning Green.

Size of Posts 5 to 7 inch face.

Distance Apart 10 feet.

Number Sound 152 3 s 87 4 s 29

Number Rotten 100 3 r 52 4 r 33

Total Number 252 139 62

Remarks: 60% s 63% s 47% s

TABLE IV

OHIO AGRICULTURAL EXPERIMENT STATION

POST TO POST RECORD

(u)—set top up. (d)—set top down. (s)—sound. (f)—fair. (p)—poor. (r)—rotten. (h)—heart post. (b)—post next to bark. In summary, (f) is classed with (s) and (p) with (r).

Owner John Hyde

Beginning at N. W. cor. of woods, go south.

1	1 u s	3 f	4 d r	>1 u s	3 d f	3 u f	3 s	3 r	4 d r
2	2 u s	2 d s	3 u s	1 s	3 s	4 d s	3 u s	3 u f	3 r
3	3 f	4 u r	3 d f	3 r	3 s	4 d s	3 f	3 r	4 u f
4	2 r	4 d r	3 u s	3 r	3 p	3 s	3 s	3 u r	3 s
5	2 u p	3 f	3 f	3 s	2 d r	4 u s	3 u s	3 s	3 p
6	2 d f	2 u s	3 s	4 u r	4 u r	4 d s	4 d r	3 r	3 p
7	2 d s	2 f	4 u s	3 d s	3 f	4 d s	4 d r	3 d p	4 d p
8	2 d f	2 s	4 u s	4 u r	4 u r	3 p	3 d r	3 s	3 r
9	2 u r	2 u f	4 r	4 u r	3 s	4 d s	4 u r	3 r	3 f
10	2 u r	2 s	4 u r	4 u r	3 f	4 u s	3 s	3 d p	4 s
11	2 d s	3 s	4 u s	3 f	4 u r	4 u s	3 u s	3 s	3 p
12	2 u r	2 s<	4 d f	3 d r	4 u r	4 d r	3 r	3 s	3 d r
13	2 u p	3 p	3 s	3 u f	3 s	tree	3 r	3 r	3 s
14	2 d r	3 r	4 d r	2 s	2 d s	3 u s	3 r	3 r	3 p
15	2 u s	3 s	4 d r	3 s	3 p <	4 s	3 r	3 r	3 f
16	4 u s	3 u f	4 u r	3 u s	4 u r	4 d s	3 r	3 s	3 f
17	2 u r	3 f	tree	3 u s	sas. r	2 u s	3 u r	3 r	4 d s
18	3 u r	3 f	3 p	3 s	2 d f	4 u f	3 s	3 u r	1 d s
19	3 u r	4 d r	3 s	3 s	2 d s	4 d s	3 s	3 r	
20	2 d s	4 u r	3 u f	3 s	2 s	3 d s	3 s	3 r	
21	2 u f	2 u r	4 u s	2 r	2 s	3 d p<	3 s	3 u r	
22	2 d s	2 d r	3 s	4 d s	2 d s	4 d s	3 u s	4 d r	
23	2 u f	2 p	3 d s	3 r	sas. r	3 s	3 s	4 u r	
24	2 u s	3 r	3 d f	3 r	sas. f	3 u s	3 f	4 u r	
25	2 u r	3 s	3 s	3 s	sas. r	3 r	3 u s	3 r	
26	3 r	4 u p	3 d r	3 f	2 d s	3 f	3 s	4 d r	
27	2 d s	4 d s	3 f	3 d f	3 u s	tree	3 u f	3 s	
28	2 s	4 u r	3 u s	3 s	4 u s	3 s	3 u f	4 u s	
29	3 u r	4 s	4 d r	3 s	4 d r	3 s	3 f	4 u s	
30	2 u s	3 r	3 r	3 s	3 u s	3 d p	2 d s	4 d f	

> —a gate. < —a culvert.

Tables III and IV are the opposite sides of the same leaf of blank book in which these data are taken. There are two pages of this kind for every fence that has been examined.

In Table IV, the shape of each post is described in order by the figure standing before each set of letters. The figure 1 stands for round post, see Fig. 1 in accompanying cut; 2 for a wedge shaped post extending from the bark to the center of the tree, see Fig. 2; 3 for one that has had the heart split off, see Fig. 3; 4 a heart post

with three corners, see Fig. 4. For example, post number 15 is a wedge shaped post that extended from the bark to the center of the tree, it was set "top up" and is sound. Number 61 is a three-cornered heart post, set "top down" and is rotten. Number 62 is a post next to the bark but with the heart split off, is set "top up" and is sound.

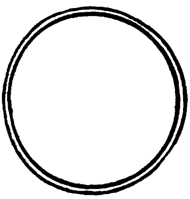

Fig. 1

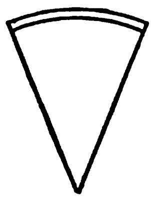

Fig. 2

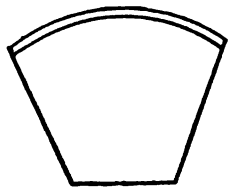

Fig. 3

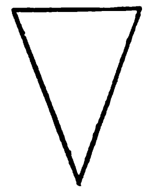

Fig. 4

It will be noticed here that 63 percent of the posts next to the bark are sound, while only 47 percent of the three-cornered, heart posts are sound.

This characteristic of rotting at the heart first has been observed to a marked extent in the locust, the oak, the hardy catalpa, the white cedar, and to some extent in the red cedar.

In the Wabash Valley, two of the most common shapes of catalpa posts are quarters and halves split from small trees; and those where decay has set in are very frequently found in the shape of a quarter-circle or a half-circle next to the sap wood or bark. The white cedar post, so common along the railroads, is frequently found in the shape of a half-circle a few inches below the top of the ground. See Plates I and II.

This fact may come as a surprise to many; indeed, some have already expressed their surprise at it and still others have refused to believe it. But when we come to look for the cause, it is not quite natural and what might be expected? Let us take for example an oak tree: the oak posts in the fence recorded in Tables III and IV have from five to seven inches face along the medullary rays. This indicates that the trees from which they were split were from 20 to 30 inches in diameter. White oak trees this size are from 150 to 200 years old. Now the only part of a tree that is alive is the part next to the bark. That part of the tree, therefore, from which these three-cornered posts were split, had been dead a hundred years or more when the tree was cut. Then, too, the center of the tree contains numerous little knots, where branches dropped off in the early life of the tree. Some of the branches in falling leave perfectly sound knots, but others offer opportunities for germs and mild decay to set in. This decay may not make any visible progress before the sap wood closes over the defect left by the falling branch,

but its effects will be there, and though it may not cause a rotten place by the time the tree is cut, it may cause the wood for some distance above and below to be a little too dark; that is, instead of bright, reddish straw-color, it will be nearer a maroon or even almost brown. Such wood may be firm and strong, and posts split from it may pass for sound ones, when as a matter of fact this hidden decay has already set in. This quality of post is by no means rare in the fences examined for the preparation of this bulletin. On the other hand, the posts split from the outside of the tree have not been standing in the tree so long, have been formed after the tree was a foot or more in diameter and had a smooth trunk, and the wood therefore is clear of knots and not subject to infections by being exposed to the air through knot holes.

It must not be understood that the white sap wood is referred to here as being durable. In estimating the size of a post split from the outside of the tree, as much post only should be counted as there is heart wood. The wood of good quality referred to here is the heart wood that lies just beneath the sap wood, as compared with the heart wood at the center of the tree.

This same tendency to rot at the heart first is seen in hollow trees and trees doted at the heart in our native woodlands.

On the following pages are given summaries of the 292 fences examined. These are grouped according to the kind of timber from which the posts were made, and six other items are given, viz.: size of posts, age or time of service, the number sound, the number rotten, the total number, and the percent of sound posts. These seven items are obtainable for the most part from every fence examined and are items vital to all. There are other items in the data recorded that are of supreme importance for certain fences, but are not common to all the fences alike. These will be discussed in the comments on the pages following the tables.

The first column of figures is simply the order of the fences of each kind of timber. The second column designates the order of the fences in the six books in which the data were recorded. The name and address of the owner of any of the fences can be obtained from those six books.

OSAGE ORANGE

		Size	Age	No. Sound	No. Rotten	Total	Percent Sound
	Book No. 1	Inches					
1	11	2-3	15	100	0	100	100
2	14	3-5	16	109	0	109	100
3	19	3-5	21	74	0	74	100
4	21	3-5	28	53	1	54	98
5	51	2½-4	26	28	3	31	90½
	Book No. 3						
6	16	2-4	15	50	0	50	100
7	26	3-5	22-12	79	0	79	100
	Book No. 4						
8	14	3-4	15	54	0	54	100
	Book No. 5						
9	1	3-5	48	104	0	104	100
10	2	2-5	33	494	2	496	99⅔
11	3	2-5	34	531	9	540	98+
12	4	5	30-35	68	2	70	97
	Book No. 5						
13	5	5-6	30	44	1	45	98
14	6	3-6	29½	29	0	29	100
15	7	2-4	28½	310	2	312	99
16	8	3-4	50	24	0	24	100
17	9	3-5	30+	126	4	130	97
18	10	4-6	40	90	0	90	100
19	11	3-4	36	38	1	39	97
20	12	6-12	58	11	0	11	100
21	12	6-12	48	28	0	28	100
22	13	1-3	40	214	7	221	97
23	14	3-5	34	29	1	30	97
24	15	6-10	49	18	0	18	100
25	16	4×4	33	17	0	17	100
26	17	3-5	38	68	4	72	94
27	18	3-5	33	92	2	94	98
28	19	3-5	40+	49	0	49	100
29	20	3-5	28+	61	4	65	94
30	21	6×6	12	332	0	332	100
31	28	3-5	21	43	0	43	100
32	29	3-4	7	130	0	130	100
33	30	2½-3	7	40	0	40	100
	Book No. 6						
34	32	2½-4	25	27	0	27	100
35	33	3-5	47	41	0	41	100
36	34	2½-4	25+	41	0	41	100
37	35	2-4	30	42	0	42	100
38	36	3-4	10+	53	0	53	100
39	37	2½-4	17	70	0	70	100
40	38	3-4	22	31	0	31	100
41	39	3-5	30	67	0	67	100

LOCUST

		Size	Age	No. Sound	No. Rotten	Total	Percent Sound
	Book No. 1						
1	12	Medium	14	23	1	24	96
2	23	"	31	22	3	25	88
3	24	Small	5	26	0	26	100
4	25	"	6½	36	8	44	82
5	26	Medium	31	45	6	51	88
6	30	"	24	67	0	67	100
7	31	"	32	115	51	166	69
8	45	"	20	126	30	156	81
9	46	"	21	143	13	156	91⅔
10	47	"	20	43	8	51	84
11	48	"	11	13	1	14	93
	Book No. 3						
12	3	Medium	20	111	21	132	84
13	7	Large	60?	20	0	20	100
14	8	Medium	60?	12	1	13	92
15	9	Large	14	63	5	68	93
16	15	Medium	8	59	0	59	100
17	19	"	30	55	6	61	90
18	20	Large	22	54	3	57	95
19	39	Medium	22	88	34	122	72
20	43	"	40	20	4	24	83
21	48	"	8	37	4	41	90
	Book No. 5	Inches					
22	27	4-6	42	27	8	35	77
23	27	4-6	25	25	1	26	96
24	31	3-5	9	32	12	44	73
25	32	3½-6	16	1173	98	1271	92
26	33	4-5	15?	147	2	149	98⅔
27	34	4-6	16	568	57	625	91
28	35	4-6	15	174	6	180	96⅔
29	36	5	17	64	0	64	100
	Book No. 6						
30	6	4-6	½	13	0	13	100
31	12	4-6	6	56	0	56	100
32	41	5-9	42	157	17	174	90
33	42	6-8	18	87	7	94	92½
34	43	4-6	22	35	0	35	100
35	44	4-6	22	68	0	68	100
36	45	4-5	29	74	49	123	60
37	46	6-7	35	62	25	87	71
38	51	4-7	17	570	70	640	89

RED CEDAR

	Book No. 1	Inches					
1	29	4-7	35	24	27	51	47
2	48	5-7	11	14	5	19	74
	Book No. 2						
3	44	5-8	50	34	19	53	64
	Book No. 4						
4	1	2-5	42	81	59	140	58
5	5	4x4	16	141	4	145	97
6	6	4-6	30	41	8	49	84
7	28	5-8	36	37	29	66	56
8	29	5-7	20	26	3	29	90
9	30	5-6	18	39	6	45	87
10	31	5-8	40+	9	8	17	53
11	32	5-8	30	48	13	61	79
12	33	5-8	50	4	9	13	31
13	34	5-7	18	71	22	93	76+
14	35	4-6	45?	20	30	50	40
15	36	5-8	40	57	19	76	75
16	37	5-8	40	102	89	191	53
17	39	8x11	63	4	4	8	50
18	41	5-9	36+	73	96	169	43
19	42	7-8	40+	11	38	49	22½
20	43	3x6	40	15	3	18	83
21	44	4-6	7	37	3	40	92½
22	45	5-7	12	68	0	68	100
23	46	5-7	14	128	2	130	98½
24	47	4-6	10	143	0	143	100
25	48	4-7	8	136	0	136	100
26	49	6x8½	62	11	2	13	85
	Book No. 5						
27	25	5-7	?	65	4	69	94
	Book No. 6						
28	9	4x4	30	38	7	45	84
29	10	4x4	30	29	16	45	64
30	11	4x4	30	35	5	40	87½
31	47	5	7	16	0	16	100
32	48	5	5	61	0	61	100

MULBERRY

		Size	Age	No. Sound	No. Rotten	Total	Percent Sound
	Book No. 1	Inches					
1	20	4-6	19	29	11	40	72½
2	38	4-6	19	40	2	42	95
3	40	5-7	13	11	2	13	85
4	41	4-6	20	57	31	88	65
	Book No. 2						
5	29	4-7	30	22	14	36	61
6	20	4-7	16	4	6	10	40
7	19	4-7	24	9	5	14	64
8	18	4-7	16	31	29	60	51⅔
9	17	4-6	24	10	7	17	59
10	11	4-6	20	4	2	6	66⅔
11	3	4-7	15	6	2	8	75
	Book No. 3						
12	4	4-7	37	41	8	49	84
13	26	4-6	22	11	2	13	84½
	Book No. 5						
14	24	4-5	?	24	7	31	77
	Book No. 6						
15	19	4-6	25	95	5	100	95

WHITE CEDAR

		Size	Age	No. Sound	No. Rotten	Total	Percent Sound
	Book No. 1						
1	20	4-6	19	31	9	40	77½
	Book No. 3						
2	21	4-7	17	122	44	166	73½
3	22	4-7	17	174	72	246	71
4	23	5-7	17	51	15	66	77
5	24	5-7	18	31	39	70	44½
6	25	5-7	20?	59	47	106	56
	Book No. 6						
7	14	5-7	15	84	7	91	92
8	23	4-5	25	33	26	59	56
9	24	4-5	25	53	17	70	76
10	25	6-9	8	738	12	750	98½
11	25	6-9	8	712	38	750	95
12	26	6-9	8	195	15	210	93
13	26	6-9	8	178	32	210	85
14	28	5-7	11	83	16	99	84

CATALPA

		Size	Age	No. Sound	No. Rotten	Total	Percent Sound
	Book No. 1						
1	1	6-9	25	14	7	21	66⅔
2	3	5x5	11	0	11	11	0
3	4	4x5	12	4	11	15	27
4	5	6-9	17	55	34	89	62
5	6	5-7	18				40
6	7	6-9	34	9	2	11	82
7	9	4-6	20	30	30	60	50
8	10	5-6	31	23	3	26	88½
9	12	5-6	14	16	8	24	66⅔
10	13	6-9	14	43	34	77	56
11	16	5-6	27	8	10	18	44½
	Book No. 2						
12	42	5-6	5½	3	9	12	25
13	39	5-6	15	256	40	296	86½
14	38	5-6	21	47	31	78	60
15	37	5-6	20	30	13	43	70
16	36	4-6	14?	97	10	107	91
17	35	5-6	16	30	17	47	64
18	35	5-6	15	6	5	11	54½
19	34	5-6	13	29	13	42	69
20	33	5-6	17	55	25	80	69
21	32	5-6	17	22	15	37	59
22	31	5-6	25	57	28	85	67
23	30	5-6	18	28	31	59	47½
24	29	5-7	30	19	17	36	53
25	28	5-6	13	17	23	40	42½
26	27	5-6	22	26	29	55	47
27	26	5-6	13	37	49	86	43
28	25	5-6	16	2	21	23	9
29	24	5-6	7	151	16	167	90½
30	23	5-8	25	9	32	41	22
31	22	5-6	16	21	25	46	46
32	21	5-6	16	38	27	65	58½
33	20	5-6	16	39	7	46	85

CATALPA—Concluded

		Size	Age	No. Sound	No. Rotten	Total	Percent Sound
	Book No. 2	Inches					
34	19	6-9	24	25	23	48	52
35	17	5-6	24	11	17	28	39
36	16	5-6	13	19	12	31	61
37	15	4-6	27	10	14	24	41⅔
38	14	6-9	18	47	42	89	53
39	12	6-8	21	34	17	51	67
40	13	5-6	15	53	3	56	95
41	11	6-8	20	56	17	73	77
42	19	6-8	23	59	58	117	50½
43	9	5-8	14	103	24	127	81
44	8	5-6	16	67	12	79	85
45	7	4-5	30	27	185	212	13
46	4	5-6	15	69	54	123	56
47	3	5-6	15	126	77	203	62
48	2	5-6	19	104	42	146	71
49	2	5-6	17	92	15	107	86
50	1	5-6	18	96	56	152	63
51	48	5-6	1	36	0	36	100
52	40	5-8	39	12	53	65	18½
	Book No. 4						
53	1	3½-6	7	93	7	100	93
54	2	3½-6	7	126	4	130	97
55	3	3-5	7	463	45	508	91
56	4	3-5	7	470	70	540	87
57	5	3-5	6½	220	21	241	91
58	6	3-5	6½	175	9	184	95
59	7	3-4½	2	100	0	100	100
60	8	3-5	6¼	103	8	111	93
61	9	4	3	100	0	100	100
62	10	4	3	173	2	175	99
63	11	4-5	3	104	0	104	100
64	12	4-5	3	212	3	215	99
65	13	4-6	6	604	22	626	96½
66	14	3-4	3	136	2	138	98½
67	15	4-5	4	138	0	138	100
68	16	3-4	16	46	12	58	79
69	17	2½-4	20	11	26	37	30
70	18	2½-4	14	91	22	113	81
71	19	4	5	181	110	191	95
72	20	2-3	6¼	270	150	420	64
73	21	2-3	4½	362	18	480	75
74	22	2½-3½	5½	208	28	236	88
75	23	2½-3½	5½	186	15	201	92½
76	24	2½-3½	5½	73	7	80	91
77	25	2½-4	9	592	188	780	76
78	26	2½	5½	39	13	52	75
79	27	4-5	3½	538	2	540	99⅔
80	28	2½-3	8	119	25	144	83
81	29	3-4	6	68	10	78	87
82	30	3½-5	6	830	20	850	98
83	31	4-5	6	684	24	708	96½
84	32	4-5	¼	60	0	60	100
	Book No. 6						
85	1	5-6	4	85	0	85	100
86	2	3-5	11	30	0	30	100
87	3	4-6	8+	12	4	16	75
88	4	5-7	6	28	4	32	87½
89	5	5-7	11	33	0	33	100
90	6	4-6	½	73	0	73	100
91	7	4-5	6	34	0	34	100
92	12	4-6	6	25	0	25	100
93	13	3-4	11	13	3	16	81
94	50	5-7	11	8	10	18	45
95	50	5-7	11	27	16	43	63

CHESTNUT

		Size	Age	No. Sound	No. Rotten	Total	Percent Sound
	Book No. 1	Inches					
1	32	5-6	9	15	3	18	83⅓
2	39	5-6	11	57	24	81	70⅓
3	39	5-6	7	37	3	40	92½
4	44	5-6	9	116	49	165	70
5	53	5-6	9	38	7	45	84⅓
6	54	5-6	8	9	5	14	64
	Book No. 3						
7	10	4-6	13	61	17	78	78
8	11	5-6	13	46	14	60	77
9	12	5-7	16	171	102	273	62½
10	13	5-6	13	77	33	110	70
11	14	5-6	13	50	51	101	50
12	18	5-6	28	8	8	16	50
13	27	5-6	11	157	74	231	68
14	50	5-6	13	22	36	58	38
15	51	5-6	12	36	34	70	51⅓
	Book No. 5						
16	22	5-6	12	42	11	53	79
17	23	5-8	8	63	4	67	94
	Book No. 6						
18	8	3-5	10	43	19	62	69

OAK

	Book No. 1						
1	27	5-6	12	19	2	21	90½
2	28	5-6	9	57	40	97	59
3	32	5-6	9	14	3	17	82
4	33	4-5	17	38	30	68	56
5	34	4-5	16	26	53	79	33
6	35	4-6	14	37	12	49	75½
7	36	4-6	14	49	21	70	70
8	37	4-6	20	21	3	24	87½
9	40	4-6	13	49	18	67	73
10	41	4-6	20	10	21	31	32
11	42	4-6	16	23	27	50	46
12	43	4-6	8	43	13	56	77
13	50	4-6	12	155	95	250	62
14	51	4-5	23	27	3	30	90
	Book No. 2						
15	34	4-6	13	25	37	62	40
16	25	4-6	16	7	13	20	35
17	11	4-6	20	21	27	48	44
18	45	5-7	13	152	100	252	60
19	45	5-7	13	187	105	292	64
	Book No. 3						
20	2	4-6	25	18	18	36	50
21	17	4-6	15	18	0	18	100
22	47	4-6	10	53	22	75	71
23	50	4-5	13	5	8	13	38½
	Book No. 5						
24	26	3-5	18	7	22	29	24
	Book No. 6						
25	20	4-5	25?	43	14	57	75½
26	27	4-5	8	31	15	46	67
27	40	5-6	18	33	3	36	92
28	45	4-5	29	11	13	24	46

HONEY LOCUST

	Book No. 3						
1	17	4-6	15	15	29	44	34
	Book No. 6						
2	15	6-8	4	83	0	83	100
3	16	5-8	4	24	0	24	100

SASSAFRAS

	Book No. 6						
1	17	5 6	4	57	0	57	100

BLACK ASH

	Book No. 6						
1	18	5-6	2	28	0	28	100
2	21	6-8	7	38	20	58	65½
3	22	6-8	6	17	10	27	63
4	29	6-7	8			*	†
5	30	6-8	9+			*	†
6	31	5-7	4½	14	2	16	87½

*Several hundred.

COMMENTS ON A FEW OF THE ABOVE FENCES THAT HAVE SOME POINT OF SPECIAL INTEREST

OSAGE ORANGE, No. 5. These posts were made from a hedge that had been kept cut back about 4 feet high for a number of years. It was allowed to grow ten or fifteen years and was then cut down at the ground and the larger ones were made into posts.

Several of these posts had defective places about 4 feet from the big end, caused by cutting the hedge back year after year at this point. The posts were set with the small end down. This put the defective place just beneath the top of the ground. The three poor or rotten posts failed at this point.

OSAGE ORANGE, Nos. 9 TO 30. These fences are in Texas. The majority of the posts are split, some are round, a few are sawed and hewed.

Nos. 20 and 21 are blocks used for the foundation of a house. These are from 6 to 12 inches in diameter. No. 24 is a lot of long posts used to support a shed around three sides of a barn. They are 6 to 10 inches in diameter. The rest are posts in ordinary fences. They range in size from 2 to 6 inches in diameter, the majority of them between 3 and 4 inches in diameter.

OSAGE ORANGE No. 29. This fence was built before barbed wire came into general use. Small holes are bored about nine inches apart along one edge of the posts. Smooth wire was fastened in these holes in such a way as to make loops (see Plate VIII). Rails split from the Osage orange tree are inserted into these loops. This makes a fence in which there is nothing but Osage orange wood and No. 9 wire. The present owner bought the farm 28 years ago. He was acquainted with it some 12 or 15 years before he bought it. The posts were in service and looked very old the first time he ever saw them.

The writer, while in conversation with the owner of fence No. 19, asked him if there was a good market for posts in that vicinity. He said they were not as ready sale as they used to be. When asked for the cause of this he replied: "Well the country was all fenced 30 to 50 years ago and we do not need any more posts."

Any one who drives about over that part of the country must conclude that this was not far from the truth, for the posts in most of the fences are rather ancient looking, frequently being in a large measure covered with moss and lichens.

This timber is certainly one of extremes. Besides its remarkable durability in the soil, it is just as remarkable in its standing qualities when seasoned, and in its elasticity.

The man just referred to above has a wagon made of Osage orange. He bought this wagon second hand, 40 years ago. Neither wheel has ever had a tire shrunk and the tires are as tight today as they were the day they were put on. The wheels, when struck a sharp blow, ring as if they were one solid piece of metal.

The wood seems to have been named from its elastic properties. The name is composed of three French words: "*bois*", wood; "*de*", "of" or "for"; and "*arc*", a bow, thus *bois d'arc* means wood for the bow. In this bulletin the term "Osage orange" is used because that name seems to be more widely understood in this state, although "*bois d'arc*" is the name almost universally used in the south-west, where the tree is native.

A well digger at Yellow Springs, Ohio has a drill that weighs about 500 pounds. His machine is constructed in such a way that, when the drill falls, the cable that supports it is stretched just as the drill strikes. This cable is

fastened to the end of a pole which must be elastic and must sustain a weight of 100 to 500 pounds. The toughest white oak or hickory in this position lasts about three months. The Osage orange pole that he has there at present has been there three years and shows no sign of weakening.

Fig. 1

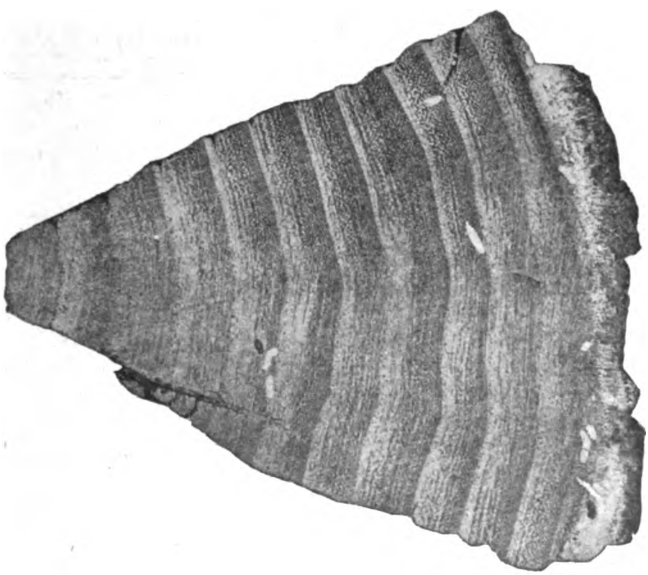

Fig. 2

Plate III. Fig. 1, Cross-section of a locust post that was sound after 31 years of service in the soil. Note how close the annual rings are. Fig. 2, Cross-section of a locust post that had rotted off in five years. Note how large the annual rings are. See page 622.

LOCUST No. 1. This is a line fence between two farmers. One man furnished locust posts, the other hardy catalpa. The posts were set alternate. Of the 24 locusts, 23 are sound; of the 24 catalpas, 16 are sound. Both kinds were seasoned when set. The posts of each kind were of fair quality except post No. 20 of the locusts. It was small and worm eaten.

LOCUST Nos. 4 AND 5. Thirty-one years ago (from the time these two fences were examined) the owner went to a locust grove, cut posts and built fence No. 5. Six years ago his son went to the same grove, cut posts and built fence No. 4. The 31-year-old fence has 88 percent sound posts, the 6-year-old has only 82 percent sound. In the 6-year-old fence, the most of the posts show very rapid growth, especially near the heart; the annual rings are from one-fourth to three-fourths of an inch thick. Many of the posts had a dark brown color, rather than a bright straw color, and a few were even doted at the heart when set. Further investigation showèd that these posts were made from trees that had grown from stumps from which the posts for the older fence had been cut 25 years before. (see Plate III).

The 6-year-old fence was examined again about two and a half years later, that is when it was nearly nine years old, and was found at that age to be only 73 percent sound. It is recorded in locust fence No. 24.

LOCUST Nos. 8, 9 AND 10. These three fences furnish some very interesting data. First, it will be noticed that No. 9, which is one year older, has 91½ percent sound posts, while the other two have only 84½ percent and 81 percent sound. All three fences are made from the same lot of posts. Selection alone is the cause of this difference. The first 75 posts in fence No. 9 are along a line between two farms, and the man who built the fence selected the larger and more perfect posts for this line. Of these 75, 72 are sound, or 96 percent.

These three fences all agree in their testimony that three-cornered heart posts show more decay than the flat ones that were split out next to the sap wood. They also show a greater percent of sound posts among those that are set with the top up than those set with the top down. The cause for this would seem to be that the post at the top end is a little smaller and therefore does not last quite as long. In oak posts split from large trees, where the taper of the post is not so evident, this difference in durability is not so noticeable.

LOCUST No. 13. This fence is interesting as a curio rather than for scientific data of any value. The posts are made from railway crossties that are said to have been put in when the Little Miami Railroad was built. They remained in the road-bed until the track was reconstructed and larger rails were put on. The ties were at that time discarded because they were so hard that the men could not drive the new spikes into them nor pull the old ones out. They were brought up to Xenia by the section foreman and put into the present position. These posts serve to show that some posts or ties of locust will endure for a remarkably long time; but they are not worth much as data upon which to estimate the durability of timber, because it is not known how many had rotted by the side of these in the track.

LOCUST No. 20. This is a garden fence in which are locust and red cedar, both of first quality, and the two kinds show the same percent of sound posts. The cedar posts are recorded in red cedar fence No. 20.

RED CEDAR No. 2. Compare this fence with red cedar No. 26. No. 2 has 74 percent sound in 11 years. No. 26 has 85 percent sound in 62 years. The posts in No. 26 are slightly larger, although those in No. 2 are good sized posts, having from 4 to 6 inches of red wood.

The wood in each case was pure, healthy growth, no indication of doted wood when posts were set. When two fences of the same kind of wood differ as widely as these when both are made of healthy wood, there is a financial or economic matter involved, that should call forth our closest scrutiny.

The posts in No. 2 grew in the open and have from 4 to 6 annual rings to the inch. Those in No. 26 have from 50 to 60 annual rings to the inch. The rings are so close that the microscope had to be used to count them (see Plates IV and V).

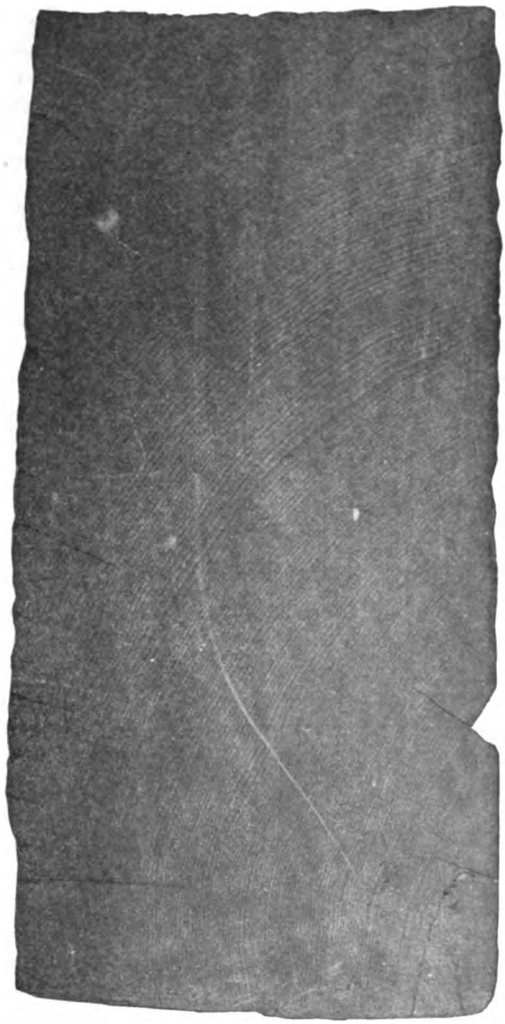

Plate IV. Cross-section of a red cedar post, sound after 62 years in the soil. The cut is the same size as the block from which it was taken. At one corner of this block there are 68 rings to one inch.

RED CEDAR Nos. 13 AND 15. No. 13 is 18 years old and about 76 percent sound. No. 15 is 40 years old and has 75 percent sound.

No. 13 has from 6 to 11 rings to the inch. No. 15 has 30 to 50.

In this case the two fences are on the same farm and begin within a hundred yards of each other. One is more than twice as old as the other, but the percent of sound posts is almost the same. Red cedar that grows in the open has wide annual rings, is apt to have large and numerous knots, a very thick sap wood, the red is not as deep color, and usually has more of those pale red or almost white spots that are commonly mixed in with the heart wood of this tree. This quality of post has been observed, a few at a place, at numerous places over the state, and they regularly show poor record. The red cedar fences, however, where there is a considerable number of posts in one string, are usually made of those that have been shipped from where they grew in the timber.

The above characteristic has been watched quite closely throughout and it is observed to be quite a regular law that the closer the rings the better the quality for posts.

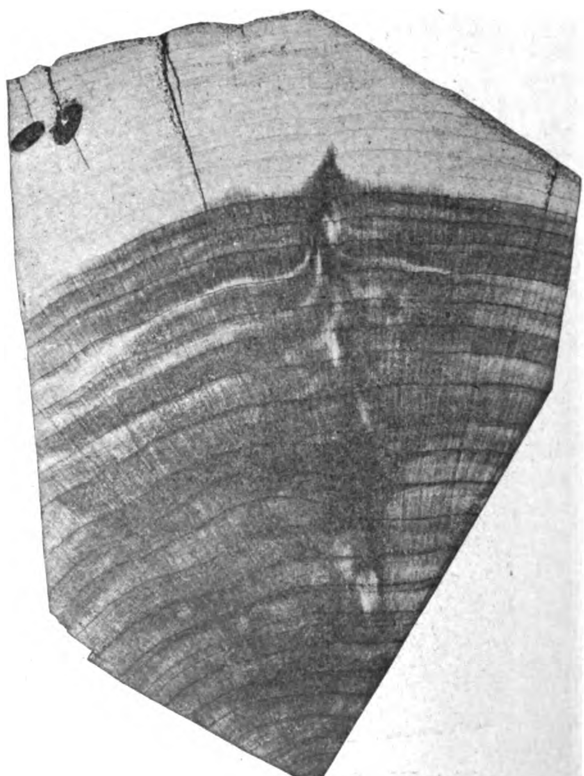

Plate V. Cross-section of a red cedar post that was rotten in 9 years. Cut was reduced one-third in diameter from the block of wood. The rings on the wood are just 4 to the inch. See pages 622-624.

RED CEDAR No. 20. These posts are set alternately with locust and have the same percent sound as the locust. Described under locust fence No. 20.

RED CEDAR No. 21. Fence is only 7 years old but is showing considerable decay, 7½ percent. Posts grew in an old field but in some places with rather thick stand. Rings are from 9 to 12 to the inch. Posts were cut in April.

RED CEDAR No. 22. Came from same grove as those in No. 21 but from denser portion. Most of these have about 20 rings per inch. The posts also average larger. Posts were cut in January. They are all sound at 12 years, while those of fence No. 21 have 7½ percent rotten in 7 years.

MULBERRY No. 1. These posts are set alternately with native-grown white cedar, 40 posts of each kind. Mulberries 72½ percent sound, cedar 77½ percent sound. The mulberries are of only moderately good quality. Compare white cedar No. 1.

MULBERRY No. 2. Posts here are of very fine quality. Note the difference between this and fence No. 1. No. 1, 19 years old, 73 percent sound, No. 2, same age, 95 percent sound. These posts were clear, bright yellow, while those in fence No. 1 frequently were too dark in color and had more little defective places. Some of them seem to have been split from trees on the decline. So much for good quality.

MULBERRY No. 3. Are set with white oak. Mulberry 85 percent sound, oak 73 percent. Mulberry posts were made from dead trees, quality not very good; cf. oak fence No. 9.

MULBERRY No. 4. A yard fence with 88 mulberry posts and 31 oak, each of good quality of its kind, each kind seasoned about one year. Mulberry 65 percent, oak 32 percent sound. This fence is a very important one, because the two kinds have had the same treatment and each is a good specimen of its kind.

MULBERRY No. 5. Fence is a mixture of mulberry and catalpa, in which the mulberry seems to be the better, each a good quality of its kind. Mulberry 61 percent, catalpa 53 percent sound; cf catalpa fence No. 24.

MULBERRY No. 6. A mixture of mulberry and catalpa in which the catalpa has the advantage. The mulberry is not a good quality of its kind. Mulberry 40 percent, catalpa 85 percent sound; cf. catalpa No. 33.

MULBERRY Nos. 7 AND 9. Mixed with catalpa, in which mulberry shows the better record. The mulberries 64 percent and 59 percent sound, catalpas 52 percent and 39 percent sound,

WHITE CEDAR No. 1. Fence contains 40 white cedar and 40 mulberry. Cedar, 77½ percent sound; mulberry, 72½ percent sound. See mulberry fence No. 1.

WHITE CEDAR Nos. 2, 3 AND 4. A large number of these posts are halves sawed from small sized trees. Those marked "p" and "f" usually show that decay began at the heart. Quite frequently, all that is left of the post where it enters the ground is a half-circle next to the sap wood. See Plates I and II.

A considerable portion of these posts had what is known as "pipe rot" when set. "Pipe rot" is a term applied to white cedar that has a little doted place or a little hollow about an inch in diameter extending through the length of the post. This is very frequent with the white cedar and dealers in selling sometimes specify that "pipe rot" shall not be considered a defect such as to bar the post thus affected from the first class.

WHITE CEDAR No. 6. All the rotten posts in this fence were removed in the summer of 1907, and locust put in their places. The locusts were taken from the east line of the farm, from a fence that was built in 1874, along a lane. The lane was abandoned in 1907 and the locust fence was moved out onto the line, and wire was put on instead of the old boards. Thus fewer posts were used. The posts that were brought over to the white cedar fence were set with the same end in the ground as in the former fence. The condition of the locust fence may be seen in locust No. 7, which was 32 years old and had 69 percent sound.

CATALPA No. 2. The posts in this fence were hewn from small trees that were mere bushes when the other timber was cut off. They were left and grew thus in the open, in rich, bottom land. They were all pure heart wood with no decayed places. The owner thought when he finished this fence that he would never have to build another in the same place. But it all went down in eleven years.

There were short posts set alternately with the regular posts. These just came to the top of the base-board of the fence. These short posts were cut from slow growth catalpas in the woods; some of them were pieces of old posts. A good percentage of the short ones were sound when the fence was removed. See Plate VI.

CATALPA No. 5. Age 18 years. The north end of this fence originally contained catalpa, mulberry, burr oak, honey locust, and sassafras. The honey locust and the sassafras are all gone. Of the other three kinds, the owner says he has taken out more oaks than any other. The south half of the fence has never had any posts removed. They are mostly catalpa and mulberry. The mulberry is in a little better condition than the catalpa.

CATALPA No. 9. Age 14 years, 66 percent sound. These are alternate with locust in fence No. 1 under locnst, and are discussed there.

CATALPA No. 12. Age 5½ years, 25 percent sound. These were cut from trees that grew in low rich land, just inside of a field, along a road. The growth was very rapid, the annual rings frequently being three fourths of an inch thick. The posts were cut just as the buds began to swell, and set green.

CATALPA No. 13. Age 15 years, 86½ percent sound. These posts stood 15 years, then were turned over and the other end was put in the ground. The exact condition therefore for these first 15 years can be seen by looking at the top of the present posts. Very few posts were discarded in resetting. If a post had rotted off in the 15 years, a piece was nailed on the top of it when reset. Posts are of fine quality, with close grain.

CATALPA No. 14. Age 21 years, 60 percent sound. Is a continuation of fence Nor 13, but this part has never been reset nor mended. It stood six years longer, or 21 years and shows 60 percent sound as compared with 82½ percent sound in the 15 year-old fence.

CATALPA No. 19. Age 13 years, fence contains 42 catalpa and 62 oak posts, catalpa 69 percent and oak 40 percent sound. Each kind only medium in quality.

CATALPA No. 22. Age 25 years, 67 percent sound, is a fine quality of catalpa grown in dense timber. No posts have ever been removed from fence. Some of these posts sent out sprouts as they stood in the fence. One of these was left and is now a tree about 40 feet tall. Posts were cut in the winter and set green. Compare catalpa fence No. 12.

CATALPA No. 25. Age 13 years, 43 percent sound. Posts were cut April. They show poor record, only 43 percent sound in 13 years though they were a good quality of timber, close grain. Compare catalpa No. 12.

Fig. 1

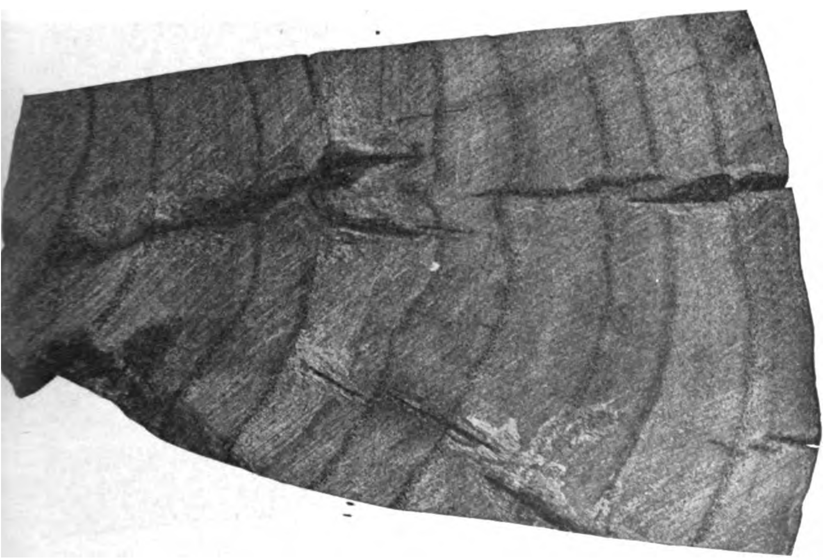

Fig. 2

Plate VI. Fig. 1, Cross-section of a catalpa post, sound after 15 years in the soil. Note how close the annual rings are. See page 626. Fig. 2. Cross-section of a catalpa post rotten in 6 years. Note the large annual rings.

CATALPA Nos. 27 AND 28. Age 13 years, 43 percent sound, and age 16 s, 9 percent sound. Many of the posts in these two fences have annual s on the outside about twice as thick as the average thickness for trees rn in dense timber. These posts were made from trees that grew in their r life among other trees which were afterwards cut away, leaving the

catalpa in an open woods. That part of these posts, therefore, which in other posts is best, that is, the part next to the sap wood, shows rapid growth. This may be the cause of the poor record in these two fences. Some oak posts in No. 28 are 35 percent sound, while catalpa in same fence are only 9 percent sound.

CATALPA No. 35. Fence contains mulberry posts also, that show 59 percent sound, while the catalpas show 39 percent sound. Has never been reset. Each is good quality of its kind; cf. mulberry No. 9. Both kinds were seasoned.

CATALPA No. 38. Is the same fence as catalpa No. 4, but one year later, showing 53 percent sound as against 62 percent sound one year before. Seasoned.

CATALPA No. 41. In same fence are 48 posts of fine quality of white oak. No posts have ever been removed. The catalpa shows 77 percent sound, the oak 44 percent; cf. oak fence No. 17. Age 20 years, well seasoned.

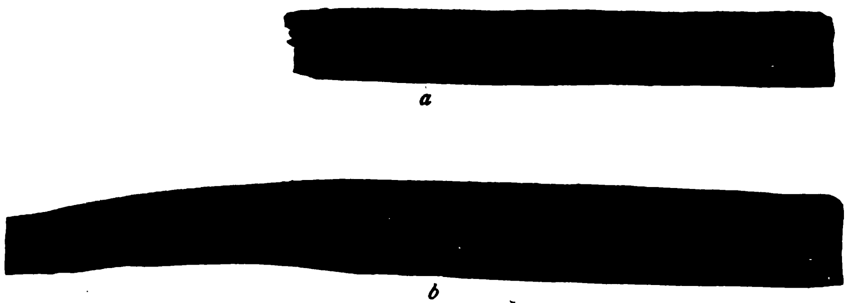

Fig. 1

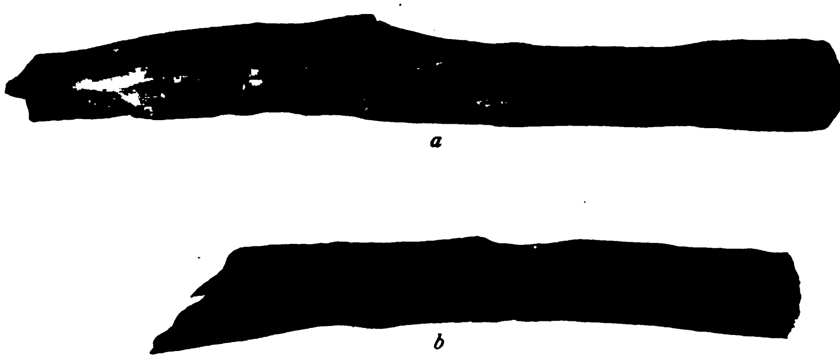

Fig. 2

Plate VII. Fig. 1, (a) Catalpa post from a fence eleven years old and all rotten. Posts in this fence are from trees of rapid growth. (b) Catalpa post from a fence 25 years old. Two-thirds of the posts are sound. Trees from which the posts were made, grew very slow in dense forest.

Fig. 2, (a) Locust post from fence 6 years old, rapid growth. (b) Locust post from a fence 31 years old, slow growth. The two fences have the same percentage of rotten posts. See page 639.

CATALPA Nos. 53-84. All the catalpa posts in fences 53-84, 8514 in number, vere grown in cultivated groves. They are all round and small, from 2½ to 5 inches in diameter at the ground. The great mass of them are between 3 and 4 inches in diameter. They were grown in Kansas, with a few exceptions in he Farlington, the Hunnewell, and the Munger plantations. The posts at the op end have from 13 to 20 annual rings, usually about 15 or 16. These rings are much wider near the center than near the bark. The first 3 rings are frequently about ½, ⅓ and ¼ inch thick; whereas on the outside it takes 8 to 10 to nake an inch. See Plate VI, Fig. 1.

The trees from which these posts were cut were planted 4 x 4 feet, and after he first few years there was of course intense crowding. This caused the outer ayers, the outside half of the post, to have about the same rate of growth and same texture as that grown in native woodlands in the Wabash valley. Since he posts are all round, that part of the post that grew slowly is next to the soil.

The sap wood of the catalpa is confined to the two outside rings. This holds good for the thrifty and the crowded tree alike. The thickness, therefore, of the sap wood in these posts is a mere trifle, frequently not more than the enth of an inch; and although the post may seem quite small, still it has a comparatively good amount of serviceable heart timber.

There is a good lesson for the tree grower in this; that is, when a grove begins to get crowded and the trees are growing more slowly, they are probably putting on a better quality of post material, and besides, the increase of serviceable post timber is more than the current year's growth would ndicate.

Let us suppose that on a given tree the annual rings for the years 1906, 907, 1908, 1909, are 1-6, 1-7, 1-8, 1-9 of an inch in thickness.

These rings represent the amount of growth of the tree in the respective years, but the layer 1-6 of an inch thick was changed to heart wood in the year 908 and the layer 1-7 of an inch thick will be changed to heart wood or serviceable wood in 1909. The increase of serviceable wood therefore for the years 1908 and 1909 is the amount that grew in the years 1906 and 1907.

So far, therefore, as these two points are concerned, it would seem advisable to let a grove stand a few years after it has become crowded.

CATALPA No. 72. These are mere stakes, about 2½ inches in diameter, all round. They were cut from little trees 7 years old. They have been in the ground 6½ years and are 64 percent sound.

This should be compared with catalpa fence No. 80, in which the posts are but little larger, 2½ to 3 inches in diameter, but were cut from trees 13 to 14 years old, growth about half as rapid as those in No. 72. Fence No. 80 is 8 years old and has 83 percent sound.

CATALPA Nos. 85-93. The posts in catalpa fences 85-93 were cut from trees that grew in Ohio in cultivated groves.

CATALPA Nos. 86 AND 88. Notice here that fence No. 86 is 11 years old and 100 percent sound and that No. 88 is only 6 years old and only 87½ percent sound.

The posts in No. 86 are very small but they are made from very slow growing trees. Those in No. 88 are from fast growing trees.

CHESTNUT No. 1. These posts are set alternately with white oak of about the same size, Chestnut 83⅓ percent sound, oak 82 percent sound; cf. oak No. 3.

CHESTNUT No. 14. Fence contains 58 chestnut and 13 oak posts, about same percent of each sound. The oak were of poor quality.

OAK No. 2. Age 9 years, 59 percent sound. Two years after this fence was examined so many of the posts were rotten that the fence had to be reset. The first eight posts at the north end of the fence are good quality of locust, one of which is rotten. These locust posts are now standing with the fourth set of oak.

OAK No. 3. Posts are 82 percent sound, set alternately with chestnut 83⅓ percent sound.

OAK No. 9. Mixed with mulberry. Oak 73 percent, mulberry 85 percent sound.

OAK No. 10. Is mixed with mulberry No. 4, age 20 years. Oak 32 percent mulberry 65 percent sound.

OAK No. 12. Most of the rotten posts here are three-cornered heart posts.

OAK No. 14. Age 23 years, 90 percent sound. These posts are made from the chinquapin oak, or white barked chestnut oak. Posts were put in the ground the same day they were split. It is a rather remarkable record for oak. They are of very fine quality.

OAK No. 15. Posts are set with catalpa in which catalpas are 69 percent and oaks are 40 percent sound; cf. catalpa fence No. 19.

OAK No. 16. These are set with catalpa that has rather rapid growth on outside of post. Catalpa 9 percent sound, oak 35 percent sound. See catalpa fence No. 28.

OAK No. 17. Catalpa and oak mixed. Catalpa 77 percent, oak 44 percent sound. Good quality of each kind. See catalpa fence No. 41.

OAK No. 18. This fence is given in detail in Tables III and IV. It will be noticed that three-cornered, heart posts here show poor record. These three-cornered ones are quite large in this fence.

There are four round sassafras posts here, Nos. 137, 143, 144 and 145. They are seven or eight inches in diameter, one is sound, three are rotten.

OAK No. 19 Age here is a little uncertain, but these are very fine quality of oak.

OAK No. 22. Fence contains 143 good quality red cedar and 75 oak posts. Cedar all sound, oak 71 percent sound. See red cedar fence No. 24.

OAK No. 23. Set with chestnut. Oak 39 percent; chestnut 38 percent sound. See chestnut fence No. 14.

HONEY LOCUST No. 1. Age 15 years, 34 percent sound. This is the only fence of honey locust of any considerable length and age that has been examined. They have been found, a few at a place, in several other fences, and have shown poor record.

BLACK ASH FENCES. I find a number of men who speak very highly of the black ash for post timber, but the fences and telephone lines in the northwest part of Ohio do not seem to justify this estimate.

In making an estimate of the worth of a given timber, several things should be considered.

It has been pointed out above that posts are frequently set that are in poor condition when set, that is, they may have been grown or cut under unfavorable conditions, or they may be too dark in color, not entirely healthy, or even doted to a considerable extent.

Fences that are made in part or entirely of such posts are not so valuable for data, since there is no means of estimating to what extent they are defective.

They may be used to show the tendency of such timber to be thus affected.

Thus for example locust fence No. 4 should be rejected in making an estimate, because the posts were of very poor quality, some of them even beginning to decay when they were set. In 6½ years 18 percent of these were rotten.

Locust No. 13 contains 20 posts that have been in service for probably 60 years and are all sound. This should not be counted in making estimates, for these were made from old railroad ties and, though these 20 show remarkable record, yet there is no way of knowing how many rotted by the side of them in the track. It would be just as fair to gather up the rotten, if that were possible, and estimate the locust from them.

Catalpa fence No. 12, which at the age of 5½ years had only 25 percent sound posts, is an extreme case. It contains two suspicious elements, very rapid growth and posts were cut just as buds began to swell.

Catalpa fences Nos. 72 and 73 should be rejected, because the posts are so small and grew rather fast, and had but little heart wood. These contain 64 percent and 75 percent sound.

Osage orange Nos. 20 and 21 should be rejected on account of large size, being from 6 to 12 inches in diameter. These are 58 and 48 years old, respectively, and none are rotten.

Red cedar No. 2 contains only 74 percent sound posts in 11 years. It should be taken into consideration where these grew, that is, out in the field.

Red cedar No. 17, 50 percent sound in 63 years, should be rejected on account of size. They are about a foot square.

Fences therefore that are to be used as a basis for conclusions should contain posts made from average timber and should contain a goodly number of posts.

The following tables contain the data on a few characteristic fences. Each fence is a good example of its kind, and none are put in this list except those on which very accurate data could be obtained. They are average fences in which the posts were sound when set. Each group will therefore reflect a comparatively correct estimate of the kind of posts that it contains.

OSAGE ORANGE

Age of Fence	Number sound posts	Number rotten posts	Total	Percent sound
28	53	1	54	98.1
33	494	2	496	99.6
29	310	2	312	99.3
36	38	1	39	97.4
40	49	0	40	100
33	17	0	17	100

Average Age, 33.2 Average Percent Sound, 99

LOCUST

31	22	3	25	88
32	115	51	166	69.3
20	126	30	156	80.8
21	143	13	156	91.7
22	111	21	132	84.1
30	55	6	61	90.1
22	88	34	122	72.1

Average Age, 25.4 Average Percent Sound, 82.3

RED CEDAR

35	24	27	51	47
42	81	59	140	57.9
36	37	29	66	56.1
30	48	13	61	78.7
18	71	22	93	76.3
38	57	19	76	75

Average Age, 33.2 Average Percent Sound, 65.2

MULBERRY

19	29	11	40	72.5
20	57	31	88	64.8
19	20	2	22	90.9
24	10	7	17	58.8
37	41	8	49	83.7

Average Age, 23.8 Average Percent Sound, 74.1

WHITE CEDAR

17	122	44	166	77.5
17	174	72	246	71
15	84	7	91	92
25	33	26	59	56
18	31	39	70	44

Average age, 18.4 Average Percent Sound, 68

CATALPA

25	14	7	21	66.6
17	55	34	89	61.8
20	30	30	60	50
14	43	34	77	55.8
21	47	31	78	60.2
25	57	28	85	67.1
22	26	29	55	47.3
13	37	49	86	43
14	103	24	127	81.1
15	69	54	123	56.1
7	463	45	508	91.1

Average Age, 17.5 Average percent Sound, 61.8

Age of Fence	Number sound posts	Number rotten posts	Total	Percent sound
	CHESTNUT			
11	57	24	81	70.4
9	116	49	165	70.3
[illegible]	61	17	78	78.2
16	171	102	273	62.7
12	42	11	53	79.2
13	77	33	110	70
Average Age, 12.3	Average percent Sound, 71.8			
	OAK			
9	57	40	97	58.8
17	38	30	68	55.9
14	49	21	70	70
13	145	97	246	58.9
8	43	13	56	76.8
10	53	22	75	69.7
Average Age, 11.8	Average Percent Sound, 65.2			
	BLACK ASH			
7	38	20	58	65.5
6	17	10	27	62.9
Average Age, 6.5	Average Percent Sound, 64.2			

It is practically impossible to arrange a set scale of percents that will show the exact value of each kind, on account of varying circumstances surrounding the fences. For example, one fence may contain posts of the very best quality of their kind while another of another kind may contain a second best. Then there are all stages of seasoning, and different kinds of soil. Then, too, the age of a fence and the percent of rotten posts do not increase at the same rate.

While, therefore, in the tables above, the average age and the average percent sound cannot be regarded as scientifically accurate, yet it is felt that they give a fair idea of the durability of the various kinds.

In the following table an effort is made to picture the relative value of the different kinds of timber by giving the percent of posts that are usually found to be sound at various ages, beginning at ten years and counting each five succeeding years up to 50 years.

When the number of sound posts falls below 50 percent, no further notice is made of it.

This table probably shows the best comparative estimate that can be given.

PERCENTAGE OF SOUND POSTS IN AVERAGE FENCES
AT AGES FROM TEN TO FIFTY YEARS

Age in Years	Osage Orange	Locust	Red Cedar	Mulberry	White Cedar	Catalpa	Chestnut	Oak	Black Ash
10	**100**	**100**	**100**	**97**	**85**	**90**	**72**	**71**	**40**
15	**100**	**95**	**97**	**80**	**78**	**72**	**62**	**61**	
20	**100**	**89**	**87**	**78**	**62**	**58**		**47**	
25	**100**	**(86)**	**(84)**	**73**	65	**53**		62	
30	**99**	**83**	**80**	**62**		**45**			
35	**98**	**(79)**	**55**	85		50			
40	**97**	83	70						
45	100								
50	100								

The numbers in parentheses are in part or entirely estimated from the numbers preceding and following; for example, it so happened that there were no locust fences examined that were exactly 25 years old, and the percent sound for this age is estimated at 86, which is half way between 89 and 83, the percentage for 20 and 30 years respectively.

It will be noticed that in each column the numbers representing the percentage of sound posts decrease to a certain point and then increase again; for example, the column under "Red Cedar" decreases until age 35 is reached. We find the average fences at this age are 55 percent sound, while the average fences at 40 years of age are 70 percent sound.

The cause of this unexpected feature is that the posts are large and of exceptionally fine quality with practically no defective posts. The important part of the table is that before this increase in percentage takes place and for this reason the first or important part is printed in bold face type.

Fences of these older ages have been found as recorded, and although they are not the types that estimates should be made from, yet it was thought best to put them in the table, but they have been put in with a different kind of type. One very important lesson that they teach is the effect brought about by the selection of good quality of perfectly sound timber.

It will be seen from the table that the Osage orange is in a class entirely alone, with no close competitor. Yellow locust and red cedar come next, very close together, with a little in favor of the locust. In the case of the red cedar, only that which grew in the woods is counted. That which grows in the open is about the same as oak in durability. Considerably below these two is mulberry. Then white cedar and catalpa quite close together; and below these, chestnut and oak, with a little in favor of chestnut; then black ash. The varieties of oak counted are white oak, chinquapin oak, burr oak, the majority being white oak. A small amount of black oak and post oak has also been examined.

Besides these varieties there have been found a few at a place of honey locust, sassafras, black walnut, white walnut and elm. The durability of these is usually poor; though some instances of excellent durability have been found in the black walnut. It is regularly poor when cut from a thrifty young tree.

The durability of some timbers seems to have been over estimated; for example, the chestnut and the hardy catalpa, especially the latter.

The author is aware that most writers on this subject class the hardy catalpa with the red cedar, the yellow locust, and the Osage orange, but the examination of 292 fences containing 30,160 posts in actual service points to the conclusion herein made, and the classification has been made in accordance with what the data indicate, regardless of any personal opinion. The fences examined were the oldest that could be found.

It is suggested that the former estimate placed on the durability of this timber seems to have been taken in a large measure from isolated posts, from old logs pulled out of river beds where they had lain for many years, or from railroad ties where no record is given of those that may have rotted in the same track while these survived. A dozen ties that have survived 25 or 30 years in the road-bed of a railroad are worth but little for data unless it is known how many of the same kind rotted in the same situation. A dozen posts that have survived 40 years in a fence are worth but little for data, unless we know the condition of all the other posts in the same fence.

Let us illustrate with a timber that we are all acquainted with. Near Albion, Illinois, there is a gate post that was an old weather-beaten post when the present owner bought the farm, just before the Civil War. This post was still supporting a gate in the summer of 1906. Near Lebanon, Ohio, is a post which supported a gate, or gates, 65 years and was then run against by a two-horse wagon, owned by the grandson of the man who set the post. It stopped the wagon and was not broken. These two posts are white oak.

At the Ohio Experiment Station, at Wooster, Ohio, is a piece of white oak timber a foot square. This piece was one end of a log 60 feet long. The entire log is sound, showing practically no decay at any point. This log has been under ground ever since the Wabash Canal was built. It was under water most of the time.

It is evident that an estimate of the durability of white oak should not be made from these three instances.

The fact should be kept very clearly in mind that *in order to have reliable data, we should have a number of fences with a considerable number of posts in each, and the condition of every post in the fences should be taken.* It would be just as fair to gather up the rotten ones and make an estimate from them alone, as to take the sound ones that have survived and make no note of the rotten ones

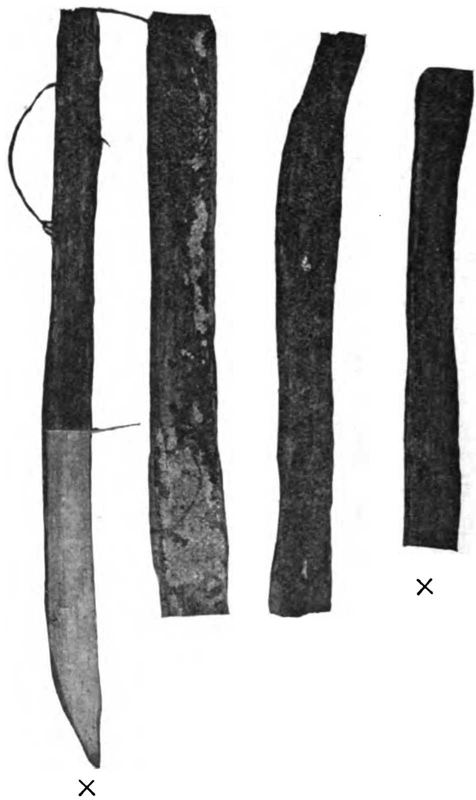

Plate VIII. Parts of two Osage orange posts, from two fences, one 30 and the other 34 years old. Each fence contains a little over 99 percent sound posts. This is about an average for the Osage orange. The pieces marked X are the parts that were in the ground. See page 620.

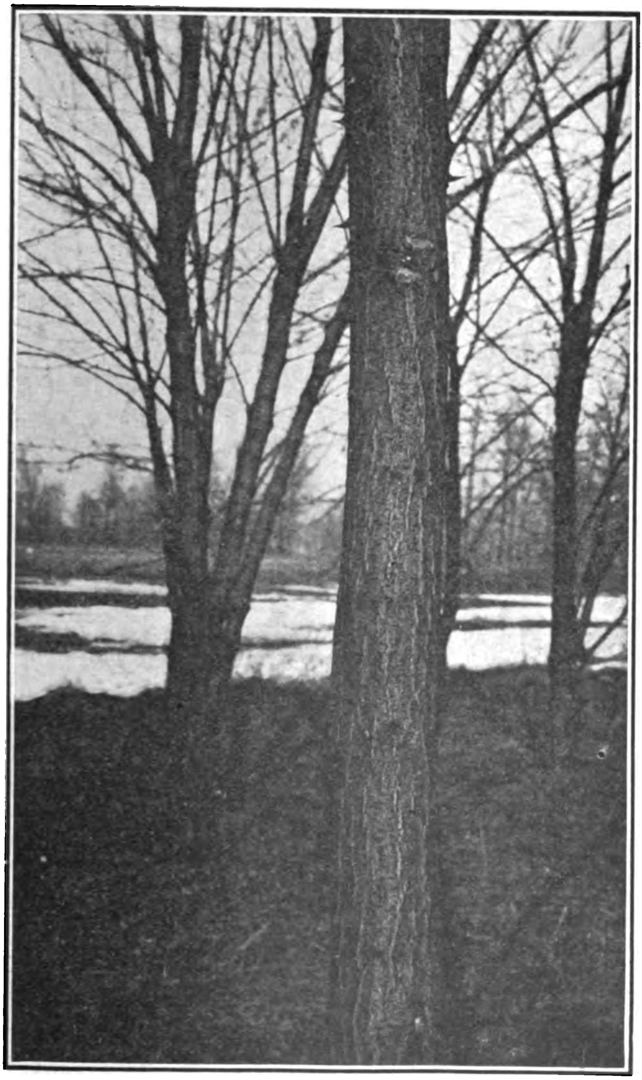

Plate IX. The trunk of a healthy young locust tree. Note the lighter colored places between the longitudinal ridges.

Plate X. The trunk of a locust tree affected with the locust borer. Notice the lumpy, uneven surface and that the bark is all dark. Compare this with Plate IX.

SOME FACTS BROUGHT OUT BY THIS INVESTIGATION

1. That a large post usually lasts longer than a small one of the same wood.

2. That there is no difference which end is put in the ground, except that the sounder or larger end should have the preference.

3. In stiff clay soil, the posts rot principally just beneath the top of the ground, and in a porous sandy or gravelly soil, they usually rot from the top of the soil all the way down; the effect is the same in both cases.

4. In soil that is full of water all the time, posts will last longer. It is the alternating between wet and dry that causes decay.

5. From data collected so far, seasoning does not seem to have any marked effect on durability. The best catalpa fence examined was set green; cf. catalpa fence No. 8. In the best oak fence examined, the posts were cut and put in the ground the same day; cf. oak fence No. 14. Likewise some of the best fences are those in which the posts were well seasoned.

It has been very difficult to get accurate data on the matter of seasoning, especially in fences where the posts have been only partially seasoned when set. But there has been a sufficient number found, in which the posts when set were well seasoned or entirely green, to justify the above conclusion. We hope, however, to be able to investigate this matter further.

6. Timber that grows rapidly and in the open is not as good as the same variety that grows in the woods. This has been observed especially in the red cedar, the catalpa, and the locust. Compare red cedar fence No. 2, 11 years old and 74 percent sound with red cedar No. 15, 40 years old and 75 percent sound; No. 2 is from rapid and No. 15 is from slow growing timber. Compare catalpa fence No. 2, 11 years old, all rotten: No. 12, 5 1-2 years old, 25 percent sound; No. 28, 16 years old, 9 percent sound; No. 72, 6 1-2 years old, 64 percent sound with catalpa No. 8, 31 years old, 88 percent sound; No. 13, 15 years old, 86 percent sound; No. 22, 25 years old, 67 percent sound. Compare locust No. 4, 6 1-2 years old, 82 percent sound with locust No. 9, 21 pears old, 91 percent sound. See Plates III, IV, V, VI and VII.

7. There is some evidence that it is not a good time to cut posts just as the tree begins to grow in early spring. This was noticed especially in catalpa fences Nos. 12 and 25 and to some extent in a number of others.

8. The wood at the center of the tree is not as good as that just inside the sap wood. This characteristic is very common with nearly all the varieties of timber examined, especially so with the locust, the white cedar, the hardy catalpa, and the oaks. See Plates I and II.

9. The quality of the wood or the condition of the wood fiber of a post is a very important item in its ability to endure in the soil. In an average lot of so-called first class posts on the market, usually a number can be selected that are defective, though they may appear sound and firm. This quality of post is usually somewhat darker than the usual color, especially near the center of the tree.

At the State Experiment Station at Wooster, Ohio, there are on file the data of every fence that was examined in this investigation. These data contain, among other items, the name and address of the owner, the location of the fence on the farm, and the date the fence was examined. Any one who feels inclined to examine any of these fences that happen to be in his community can get their location by writing to the Forestry Department of the Experiment Station.

TWENTY-NINTH ANNUAL REPORT
FOR 1909-1910
METEOROLOGICAL SUMMARY,
PRESS BULLETINS,
INDEX.

OHIO

Agricultural Experiment Station

WOOSER, OHIO, U. S. A., JULY, 1910.

BULLETIN 220

The Bulletins of this Station are sent free to all residents of the State who reqest them. When a change of address is desired, both the old and the new address should be given. All correspondence should be addressed to EXPERIMENT STATION, Wooster, Ohio

Twenty-ninth Annual Report

OF THE

Ohio Agricultural Experiment Station

For the Year ending June 30, 1910

Published by order of the State Legislature

WOOSTER, OHIO
EXPERIMENT STATION PRESS
1910

Museum of
Comparative Zoology

ANNOUNCEMENT

The Ohio Agricultural Experiment Station is organized under an act of the General Assembly of Ohio, passed April 17, 1882, and supplemented by an act of Congress, approved March 2, 1887.

WHAT THE STATION CAN DO

The Station offers its advice and assistance to the farmers of Ohio along the following lines:

The maintenance of soil fertility, including the rotation of crops and the selection and use of manures and fertilizing materials.

The selection of varieties of grains, grasses and forage crops and methods of culture.

The selection of varieties of fruits and vegetables and the management of orchards.

The examination of seeds that are suspected of being unsound or adulterated; the identification of grasses, weeds and other plants; the prevention of fungous diseases of plants.

The identification of insects and the control of such as are injurious.

The feeding of animals, including calculation of rations and use of various feeding stuffs.

The planting and care of forest trees and the management of farm woodlots.

WHAT THE STATION CANNOT DO

The Station is not prepared to analyze commercial fertilizers and feeding stuffs, as in Ohio that work is placed in charge of the SECRETARY OF THE STATE BOARD OF AGRICULTURE, at Columbus, to whom all requests for such analyses should be addressed.

The Station is not prepared to give advice respecting treatment of contagious diseases of animals, that function having been transferred to the State Board of Agriculture in its capacity of STATE LIVE STOCK COMMISSION. Requests for such advice should be addressed to SECRETARY, STATE LIVE STOCK COMMISSION, Department of Agriculture, Columbus, Ohio.

The Station is not prepared to examine animals suspected of having been poisoned. Such examinations should be referred to the nearest Veterinarian.

The Station is not prepared to make official inspection of orchards and nurseries under the law requiring such inspection, that work having been transferred to the STATE BOARD OF AGRICULTURE to whose SECRETARY, Columbus, requests for such inspection should be addressed.

The Station is not prepared to examine foods, drugs and dairy products suspected of adulteration, as that work is in charge of the OHIO DAIRY AND FOOD COMMISSIONER whose office is at Columbus.

The Station is not prepared to analyze drinking water; requests for such analysis should be addressed to the SECRETARY OF THE STATE BOARD OF HEALTH, Columbus.

Visitors to the Station or its various test farms are welcome at all times during business hours. Persons or parties who contemplate such visits and who desire special attention are requested to write in advance, giving date of proposed visit and probable number of party.

Any citizen of Ohio has the right to apply to the Station for such assistance as it can give, and all such requests will receive prompt attention.

The Bulletins of this Station are sent free to all residents of the State who request them.

Address all communications to

EXPERIMENT STATION,

Wooster, Ohio.

OHIO AGRICULTURAL EXPERIMENT STATION

BOARD OF CONTROL

John Courtright, *President* .... Ashville
Henry L. Goll, *Secretary* .... Swanton
D. L. Sampson, *Treasurer* .... Cincinnati
George E. Scott .... Mt. Pleasant
Joseph D. Guthery .... Marion

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- Lemuel D. Harrold, *Clerk*
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- C. A. Patton, *Asst. Foreman, Meteorologist*
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- R. D. Whitmarsh, B. S., *Assistant*

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- J. J. Crumley, Ph. D., *Assistant*

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- F. H. Ballou, *Assistant*
- Ora Flack, *Foreman of Orchards*
- W. E. Bontrager, *Foreman of Grounds*
- Chas. G. Laper, *Foreman of Greenhouse*

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- R. C. Collison, M. S., *Assistant*
- M. Helen Keith, A. M., *Assistant*

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- Thos. F. Manns, M. S., *Soil Bacteriologist*
- Edward Mohn, *Supt. Test-farm*, Strongsville
- Lewis Schultz, *Supt. Test-farm*, Carpenter
- Henry M. Wachter, *Supt. Test-farm*, Germantown

REPORT OF THE BOARD OF CONTROL

To His Excellency, JUDSON HARMON, *Governor of Ohio:*

SIR: I have the honor of submitting herewith the twenty-ninth annual report of the Ohio Agricultural Experiment Station, for the year ended June 30, 1910.

STATE APPROPRIATIONS

The following sums were appropriated by the last General Assembly for the support of the Station during the current fiscal year:

For Department of Administration	$26,300	
" " " Agronomy	16,475	
" " " Animal Husbandry	15,000	
" " " Botany	10,900	
" " " Chemistry	3,700	
" " " Cooperative Experiments	20,470	
" " " Dairy Husbandry	8,000	
" " " Entomology	5,000	
" " " Forestry	10,000	
" " " Horticulture	10,950	
" " " Nutrition	4,000	
" " " Soils	10,500	
" Furniture and Carpets	500	
" Improvement of Road	500	
" Completing Nutrition Building	17,000	
" Extension of Power House	3,000	
" Purchase of land	4,000	
Total		$166,295

These appropriations provide for extension of work along several lines, including the establishment of a new department, that of Dairy Husbandry, the need for which was emphasized in our last annual report. This department will be organized at once.

The appropriations provide for the completion of the building for the work of the Department of Nutrition, for which an appropriation of $5,000 was made by the previous Assembly. This building will include an abattoir and cold storage facilities of sufficient extent to accommodate the Departments of Animal Husbandry, Dairy Husbandry and Horticulture, as well as that of Nutrition.

Three thousand dollars is provided for extension of the Power House and four thousand for the purchase of land, which will be expended in the purchase of a lot near the Station grounds on which stands a large dwelling which will be used temporarily for office purposes, the present offices having become so crowded that additional room for this purpose is absolutely necessary. This dwelling is, of course, ill adapted to office purposes, while it is urgently needed by the Station for residence purposes, as is shown by the fact that of the 70 persons employed in the Station offices, 60 are compelled to find homes in town, from one to two miles from their work. This, of course, would not be a serious matter if there were a street car line with frequent service between the Station and town, but there is no such line. The Station now owns seven dwellings on the central farms, which are rented to employes at rates that bring in a fair interest on their value. It could use two or three times this many with a saving to the State much more than equivalent to their rental value. The most urgent need of the Station, however, is for larger office and laboratory facilities, and we renew our request for the following buildings:

1. An addition to the administration building, to provide new quarters for the Department of Agronomy, Horticulture and Forestry, and to permit the extension within the present building of the botanical and entomological laboratories. This addition will necessarily be built of stone and in fireproof construction.

2. A chemical laboratory of sufficient capacity to bring under one roof the two laboratories now in operation, thus facilitating economy in equipment and operation, and releasing the present rooms for other purposes to which they are better adapted and for which they are much needed. The laboratory should be of fireproof construction.

THE GERMANTOWN TEST FARM

In the spring of 1902 provision was made by the General Assembly in the appropriations to the Experiment Station for the establishment of a sub-station or test farm, to be located in the Miami Valley, and to have as one of its chief lines of work the study of problems relating to the culture of tobacco.

The Board of Control visited this region and selected a tract of 53 acres, lying less than a mile east of Germantown, Montgomery county, and since included within the corporate limits of that municipality. This tract was purchased by the President of the Tobacco Growers' Union, of Germantown, and leased to the Experiment Station for ten years at an annual rental of six percent on the purchase price, giving the Station the option of taking over the land at any time during the 10-year period on payment of the original purchase price.

This land proves to be admirably adapted to the work, and the experiments which were begun on it in 1903, and which include not only the culture of tobacco, but also of corn, wheat and clover, are yielding results of very great value to the agriculture of that region. As the option on this land will expire September 30th, 1912, and as the land is now worth much more than the option price, this option should be closed and the land purchased by the State.

Work of this kind is cumulative in character. One season's results, standing alone, have but little value; a number of seasons, with their varying climatic conditions, must be passed through before conclusions can safely be drawn, and even after 10 years' work it is to be expected that succeeding seasons will bring new developments, as is already being shown in the older tests at the Central Station. To discontinue this work now, therefore, would mean the loss of a large part of what has been accomplished.

COUNTY EXPERIMENT FARMS.

A bill introduced by Hon. George M. Wilber, of Union County, has become a law in the following form:

AN ACT

To supplement section 1165 by the enactment of sections 1165-1, 1165-2, 1165-3, 1165-4, 1165-5, 1165-6, 1165-7, 1165-8, 1165-9, 1165-10, 1165-11, 1165-12 and 1165-13 to authorize the establishment of county experiment farms.

Be it enacted by the General Assembly of the State of Ohio:

SECTION 1. That section 1165 of the General Code be supplemented by the enactment of sections 1165-1, 1165-2, 1165-3, 1165-4, 1165-5, 1165-6, 1165-7, 1165-8, 1165-9, 1165-10, 1165-11, 1165-12 and 1165-13 to read as follows:

Sec. 1165-1. In order to demonstrate the practical application under local conditions of the results of the investigations of the Ohio Agricultural Experiment Station, and for the purpose of increasing the effectiveness of the agriculture of the various counties of the state, the commissioners of any county in the state are hereby authorized and empowered to establish an experiment farm within such county as hereinafter provided for.

Sec. 1165-2 The experiment farms established under this act shall be used for the comparison of varieties and methods of culture of field crops, fruits and garden vegetables; for the exemplification of methods for controlling insect pests, weeds and plant diseases; for experiments in the feeding of domestic animals and in the control of animal diseases; for illustrations of the culture of forest trees and the management of farm woodlots; and for the demonstration of the effects of drainage, crop rotation, manures and fertilizers, or for such part of the above lines of work as it may be practicable to carry on.

Sec. 1165-3. Upon the filing of a petition with the county auditor signed by not less than five per cent. of the electors, based upon the vote for governor at the last preceding election, residing within the county, the commissioners of

such county shall submit to the qualified voters of such county a proposition to establish an experiment farm within such county, and to issue notes or bonds for the purchase and equipment of such farm, such proposition to be voted upon at the next general election following the receipt of the petition by the commissioners. Notice of the intention to submit such proposition shall be published by the county commissioners in two newspapers of opposite politics printed and of general circulation in said county, for at least four weeks prior to the election at which the proposition is to be voted upon, together with a statement of the maximum amount of money which it is proposed to expend in the purchase and equipment of such farm.

Sec. 1165-4. The county auditor shall file a written request with the board of deputy supervisors of elections asking for the preparation of the necessary ballots, which ballots shall be separate and apart from all other ballots, and which ballots shall have printed thereon "Tax for experiment farm—yes"; "Tax for experiment farm—no". The result of such election shall be ascertained by the board of deputy supervisors of elections and the result thereof certified to the county auditor.

Sec. 1165-5. If a majority of the electors voting on such proposition in the county, are in favor of establishing such experiment farm, then the commissioners of the county shall levy a tax on all the taxable property in such county as listed for taxation on the county duplicate, which levy shall not exceed one-fifth of one mill on the dollar of the taxable property of the county in any one year, nor shall the aggregate of all levies for such purpose exceed two mills on the dollar.

Sec. 1165-6. To anticipate the collection of the tax authorized by this act and the use of the money to be raised thereby, the commissioners are hereby authorized and required to issue the notes or bonds of their county, such notes or bonds to bear interest at a rate not to exceed six per cent. per annum, and not to run to exceed ten years, and not to be sold for less than their par value, and the proceeds of the sale thereof shall be deposited in the county treasury, to be applied by the commissioners to the purchase and equipment of an experiment farm, containing eighty acres or more, as hereinafter provided for.

Sec. 1165-7 When the funds provided for in this act are deposited in the county treasury, the commissioners shall notify the board of control of the Ohio Agricultural Experiment Station of their action, on receipt of which notice it shall be the duty of said board of control to visit the county and assist in the selection of a farm to be used for the purpose specified in this act, provided that no farm shall be purchased except with the approval of the majority of the members of said board of control and also of a majority of the board of county commissioners of the county.

Sec. 1165-8. The equipment of an experiment farm shall consist of such buildings, drains, fences, implements, live stock, stock feed and teams as shall be deemed necessary by the board of control of the experiment station for the successful work of such farm, and the initial equipment shall be provided by the county in which the farm is established, together with a sufficient fund to pay the wages of the laborers required to conduct the work of such farm during the first season. The county commissioners shall appropriate for the payment of the wages of laborers employed in the management of such farms as may be established under this act, and for the purchase of supplies and materials necessary to the proper conduct of such farms such sums not exceeding two thousand dollars annually for any farm, as may be agreed upon between said commissioners and the board of control of the experiment station.

Sec. 1165-9. The management of all experiment farms established under authority of this act shall be vested in the director of the Ohio Agricultural Experiment Station, who shall appoint all employees and plan and execute the work to be carried on, in such manner as in his judgment will most effectively serve the agricultural interests of the county in which such farm may be located, the director and all employees being governed by the general rules and regulations of the board of control of said Experiment Station.

Sec. 1165-10. Before entering upon any line of investigation or demonstration upon any of the experiment farms established under this act, the director of the experiment station shall submit a written plan of such contemplated work to an advisory board, consisting of the county agricultural society of the county in which such experiment farm may be located, or if there be no county agricultural society, then of the board of county commissioners of such county, and if such plan is not approved by such advisory board, then the work shall not be undertaken.

Sec. 1165-11. The county commissioners of any county may assign to the board of control of the Experiment Station such portion of any farm now owned by the county as may be mutually agreed upon between the commissioners and the board of control, the land thus assigned to be occupied and used by the experiment station for the purpose specified in this act and under the management of the director of the station.

Sec. 1165-12. The produce of each of such experiment farms as may be established under this act, over and above that required for the support of the teams and live stock kept on the farm, shall be sold and the proceeds applied to the payment of the labor and to the purchase of the supplies and materials required for the proper management of the farm as contemplated by this act, and for the maintenance of its equipment. Any surplus beyond these requirements shall be covered into the county treasury and placed to the credit of the general fund of the county, except in case of the use of farms already belonging to the county, in which case the proceeds shall be placed to the credit of such fund as the county commissioners may designate.

Sec. 1165-13. In case the experiment station shall cease to use for the purposes herein specified any farm established under this act, such farm and its equipment shall be sold at public auction to the highest bidder after notice of such proposed sale shall have been published for four consecutive weeks in two newspapers of opposite politics, once a week, published in and having the largest circulation in the county within which the farm is located, and the proceeds of such sale shall be covered into the county treasury, the sums thus covered to be placed to the credit of the school funds of the county.

GRANVILLE W. MOONEY,
Speaker of the House of Representatives.
FRANCIS W. TREADWAY,
President of the Senate.

Passed April 13, 1910.
Approved April 23, 1910.
JUDSON HARMON, Governor.

This law, it will be observed, is wholly optional in character merely providing a way by which the counties may inaugurate local demonstrations of the results which are being worked out at the central Station, and by which local problems and conditions may be more efficiently and thoroughly studied by the Station.

It is proper to state that this measure did not originate with the Experiment Station, but with a sub-committee of the Finance Committee of the House of Representatives, of which Mr. Wilber was a member, on their visit to the Station to inquire into its work and needs.

PERSONNEL

The term of office of Dr. W. I. Chamberlain having expired, Hon. Joseph D. Guthery, of Marion County, was appointed to succeed him.

At the annual meeting of the Board, held in March, the following organization was affected: President, John Courtright; Secretary, Henry L. Goll; Treasurer, D. L. Sampson.

Respectfully submitted,

HENRY L. GOLL,

Secretary of the Board of Control.

REPORT OF THE BURSAR.

MR. JOHN COURTRIGHT, *President of the Board of Control:*

DEAR SIR: I respectfully submit herewith the financial report of the Station for the fiscal year ending June 30, 1910.

In statements A, B, C, D and E, respectively, will be found a record of receipts and expenditures from the various funds; statements A and B being statements of account with the appropriations received from the U. S. Treasury and a copy of the report made to the Governor of the State, the U. S. Secretary of Agriculture, and the Secretary of the U. S. Treasury: statment C being a statement of account with the State Treasury, and statement D showing the receipts from farm produce and other sources and the expenditures from that fund.

The four statements, A, B, C, and D. are combined in statement E, which shows the total income and expenditures for the fiscal year.

STATEMENT A

Hatch Fund

THE OHIO AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH THE UNITED STATES APPROPRIATION UNDER THE HATCH ACT FOR 1909-1910.

Dr.

To receipts from the Treasurer of the United States, as per appropriation for the fiscal year ending June 30, 1910, as per act of Congress approved March 2, 1887		$ 15,000.00

Cr.

By expenditures for:—		
Salaries	$13,857.50	
Publications	260.00	
Postage and stationery	100.17	
Traveling expenses	17.33	
Contingent expenses	15.00	
Buildings and repairs	750.00	
Total		$ 15,000.00

STATEMENT B

Adams Fund

THE OHIO AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH THE UNITED STATES APPROPRIATION UNDER THE ADAMS ACT FOR 1909-1910

Dr.

To receipts from the Treasurer of the United States, as per appropriation for the fiscal year ending June 30, 1910, as per act of Congress, approved March 16, 1906	$ 13,000.00

Cr.

By expenditures for:—

Salaries	$9,765.00	
Labor	367.32	
Chemical supplies	717.50	
Seeds, plants and sundry supplies	15.29	
Library	66.43	
Scientific apparatus	1,144.32	
Live stock	193.00	
Traveling expenses	81.78	
Building and repairs	649.36	
Total		$ 13,000.00

We, the undersigned, duly appointed Auditors of the Corporation, do hereby certify that we have examined the books and accounts of the Ohio Agricultural Experiment Station for the fiscal year ended June 30, 1910, that we have found the same well kept and classified as above; that the receipts for the year from the Treasurer of the United States are shown to have been $15,000.00 under the act of Congress of March 2, 1887, and $13,000.00 under the act of Congress of March 16, 1906, and the corresponding disbursements $15,000.00 and $13,000.00; for all of which proper vouchers are on file and have been examined and found correct.

And we further certify that the expenditures have been solely for the purposes set forth in the acts of Congress approved March 2, 1887, and March 16, 1906, and in accordance with the terms of said acts, respectively.

Signed:

JOSEPH D. GUTHERY,
D. L. SAMPSON,
Auditors.

STATEMENT C

State Appropriations

THE OHIO AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH THE STATE TREASURY

Date of appropriation	Appropriation for:—	Total amount to Station's credit	Total amount expended	Balance in treasury June 30, 1910
1910	Administration	$ 26,300.00	$ 5,084.81	$ 21,215.19
	Furniture and Carpets	500.00		500.00
	Agronomy	16,475.00	3,194.34	13,280.66
	Animal Husbandry	15,000.00	3,970.52	11,029.48
	Botany	10,900.00	1,711.24	9,188.76
	Cooperative Experiments	20,470.00	6,162.55	14,307.45
	Entomology	5,000.00	765.14	4,234.86
	Forestry	10,000.00	2,339.42	7,660.58
	Soils	10,500.00	2,963.16	7,536.84
	Chemistry	3,700.00		3,700.00
	Horticulture	10,950.00	2,648.68	8,301.32
	Nutrition	4,000.00	61.15	3,938.85
	Dairy Husbandry	8,000.00		8.000.00
	Completing Nutrition Building	17,000.00		17,000.00
	Purchase of land	4,000.00		4,000.00
	States share of assessment for road construction	500.00		500.00
	Extension of Power House	3,000.00		3,000.00
	Totals for 1910	$166,295.00	$ 28,901.01	$137,393.99
1909	Administration	$ 15,203.79	$ 15,203.79	
	Agronomy	8,302.01	8,302.01	
	Animal Husbandry	12,249.06	12,249.06	
	Botany	4,066.39	4,066.39	
	Cooperative Experiments	11,379.94	11,379.94	
	Entomology	5.551.24	5,551.24	
	Forestry	6,847.98	6,847.98	
	Soils	4,115.94	4,115.94	
	Furniture and Carpets	857.80	426.53	431.27
	Chemistry	3,180.62	2,454.73	725.89
	Horticulture	7,673.72	7,673.72	
	Nutrition	7,925.60	3,189.48	4,736.12
	Totals for 1909 and 1910	$253,649.09	$110,361.82	$143,287.27

STATEMENT D

Produce Fund

THE OHIO AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH THE PRODUCE FUND

Dr.

To Receipts

From Department of Administration	$ 800.50	
" " " Agronomy	1,369.61	
" " " Animal Husbandry	7,199.90	
" " " Botany	.70	
" " " Cooperative Experiments	2,246.78	
" " " Entomology	37.60	
" " " Forestry	177.26	
" " " Horticulture	3,741.42	
" " " Nutrition	365.77	
" " " Soils	2,019.71	
Total receipts for the year		$ 17,959.25
To balance brought forward July 1, 1909		5,973.26
Total		$ 23,932.51

Cr.

By Expenditures

For Salaries	$ 2,533.34	
" Labor	2,262,83	
" Postage and stationery	285.67	
" Freight and express	451.35	
" Heat, light, water and power	323.02	
" Chemical supplies	225.03	
" Seeds, plants and sundry supplies	1,412.40	
" Fertilizers	32.50	
" Feeding stuffs	3,592.69	
" Library	56,35	
" Tools, implements and machinery	1,674.82	
" Scientific apparatus	15.25	
" Live stock	3,237.16	
" Traveling expenses	1,192.61	
" Contingent expenses	306.83	
" Buildings and repairs	4,121,08	
Total expenditures for the year		$ 21,722.93
By balance carried forward		2,209.58
Total		$ 23,932.51

STATEMENT E

Totals

TOTAL RECEIPTS AND EXPENDITURES OF THE OHIO AGRICULTURAL EXPERIMENT STATION FOR THE YEAR ENDING JUNE 30, 1910.

Dr.

Total Receipts

From United States Appropriations	$ 28,000.00	
" State appropriations	166,295.00	
" Produce Fund	17,959,25	
Total receipts for the year		$ 212,254.25
To balance brought forward July 1, 1909		93,327.35
Totals		$ 305,581.60

Cr.

By Expenditures

For Salaries	$ 55,443.89	
" Labor	31,882.12	
" Publications	7,778.80	
" Postage and stationery	1,722.65	
" Freight and express	2,774.65	
" Heat, light, water and power	2,659.98	
" Chemical supplies	2,636.89	
" Seeds, plants and sundry supplies	8,097.38	
" Fertilizers	1,020.69	
" Feeding stuffs	6,121.65	
" Library	855.13	
" Tools, implements and machinery	6,592.46	
" Furniture and fixtures	426.53	
" Scientific apparatus	3,206.70	
" Live stock	8,085.67	
" Traveling expenses	9,289.69	
" Contingent expenses	613.77	
" Buildings and repairs	10,876.10	
Total expenditures for the year		$ 160,084.75
By balance carried forward		145,496.85
Total		$ 305,581.60

Respectfully submitted,

W. H. KRAMER, *Bursar.*

REPORT OF THE DIRECTOR

HON. JOHN COURTRIGHT, *President of the Board of Controi:*

SIR: I have the honor of submitting the following report of the work of this Station for the year ended June 30, 1910.

THE STATION'S WORK

In general the work of the Station has followed closely along the lines described somewhat in detail in my last report.

The principal features of the work of the year have been as follows:

AGRONOMY

Varietal and cultural work. The work of the Agronomy department is being continued along lines similar to those of last year with the following field crops: Alfalfa, clover, corn, cowpeas, special forage crops, meadow grasses, oats, soybeans and wheat. This work includes the testing of old and new varieties; the testing of methods, rates and times of seeding, and the improvement of existing varieties by plant selection and breeding.

In the testing of varieties some 25 different sources of alfalfa seed are being studied; 35 varieties of corn, 25 of which are pedigreed strains developed in our ear-row breeding; 4 varieties of field peas; 10 species of grasses; 60 varieties of oats in tenth-acre plots and 74 in hundredth-acre plots; 51 varieties of soybeans, 34 of which are superior pure line selections in hundredth-acres.

In the study of methods of seeding, work is being carried on with alfalfa, clover, corn and oats. In rate of seeding, with alfalfa, corn, oats, soybeans and wheat. On the best time of seeding, with alfalfa, corn oats and wheat. On the relation of size and weight of seed to yield, with oats and wheat.

Crop improvement work. In this work 130 strains of alfalfa are being propagated from seed from as many different plants; 245 strains of red clover; 100 strains of corn; 569 strains of oats; 125 strains of soybeans and 1560 strains of wheat.

The work in crop improvement is oldest with corn. Pedigreed strains have been developed which are thus far yielding 5 to 14 bushels per acre more than than the original varietes from which they have been selected and bred; pedigreed strains of oats and wheat are yielding 3 to 6 bushels in advance of original stock, and of soybeans, 2½ to 6 bushels.

In studies in corn of the relation of prominent ear characters to yield, evidence is accumulating showing that the use of seed ears of less than normal length for a given variety or locality will reduce the yield, and that the continuous use of ears having an inch to an inch and a half of bare cob at the tip decreases the yield of shelled corn per acre. In other words this character seems to be hereditary; that ears comparatively smooth in indentation—merely crease dented, are somewhat superior in yield to very rough-dented ears; that when the conditions of growth are equal, and the ears compared are equal in maturity, weight of ear is a partial guide in the selection of productive seed, and that shape of ear as regards cylindricity is a matter of less importance than the above mentioned characters.

New work. Milling and baking tests of the Station's different varieties and selections of wheat are now in progress. These tests are showing interesting variations and will prove of value to the State when they have been confirmed by repeated tests made during several different seasons.

Cooperative work. Cooperative work is being carried on by farmers in several counties of the State in the testing of corn, soy-beans, oats and wheat. It is proposed to extend this work very largely.

A study of two systems of farming, one with, the other without livestock, has been inaugurated.

ANIMAL HUSBANDRY AND DAIRYING

The lines of work reported upon last year are being continued. A study of the various proportions of grain and roughage in the ration for beef production has been begun, and in the use of various roughages for mutton production.

New work. Studies in wool production have been begun. This work will be prosecuted from the standpoints of both the wool producer and and the textile worker.

Experiments in pasture improvement have been undertaken at the Central Station and the Southeastern Test-farm, which it is hoped to extend to other sections of the State.

Work with poultry has been begun on a limited scale at the Southeastern Test-farm. It is planned to extend this work as fast as the Station's resources will permit.

Buildings. During the past year a much needed swine barn has been erected, and the barn occupied by the breeding and dairy cattle has been so altered and repaired as to make it more sanitary and convenient. Funds are now available for erecting a storage and sheep barn at the Southeastern Test-farm.

The last General Assembly having made provision for a Department of Dairying, the Department of Animal Husbandry will hereafter include the production of meat and wool and the feeding of horses.

When the Department of Dairying is organized the management of the dairy cattle will be transfered to this department.

BOTANY

Three separate lines of work are included in the Department of Botany, namely: I—Examination of seeds for purity and germinability, and identification of weeds, with suggestions for their control. II—the investigation of plant diseases and of methods for their control, and III—Plant breeding work with tobacco.

Seeds and weeds. About 425 samples of seeds have been tested during the year for purity, and germinatian tests have been made of about 200 samples. An effort is made to identify such seed impurities as the dodders and plantains in clover and alfalfa and to detect the adulteration of seeds with inferior varieties. It is hoped that this work may be placed by law with the State Department of Agriculture under a general provision for seed inspection and control. Numerous collections of weed seeds made by pupils in country schools have been identified.

Weed spraying. In 1909 some preliminary work was done in this method of weed control with encouraging results, and the last General Assembly has increased the appropriations to this department of the Station by $1000, to be used in further investigations along this line. Preparations are being made to give this method a thorough test during this season.

Plant diseases. This phase of the work of the department includes several more or less separate lines of work. During the past two years the diseases of the cereals have received special attention. The bacterial blight of oats, which caused such a loss in this crop of 1907 and 1908, is reported upon in Bulletin 210. Some diseases in corn and greenhouse crops, truck crops and fruits, are now under investigation, both through laboratory investigations at the Station and by field experiments in cooperation with fruit growers and truck gardeners.

Diseases of forest and shade trees. Special provision was made for this work in the appropriations for the current year, and it is being undertaken in cooperation with the Forestry Department of the Station.

Plant breeding. For some years the Department of Botany has carried on work in the hybridizing of wheat and oats. A few hybrids obtained in this way are being tested out at the Station and on the outlying test farms. The principal part of the breeding work of this department is being conducted on tobacco, in response to the request of the Tobacco Growers' Union, made at the time the Germantown Test-farm was established. Several hundred tobacco

hybrids are now under investigation, some of which are quite promising. The Bureau of Plant Industry, of the U. S. Department of Agriculture, has assigned a special agent, to work during 1910 in cooperation with this Station in tobacco investigations.

CHEMISTRY

The Chemical Department continues to be chiefly occupied in studies of the relationship between the chemical composition of soils and crops. Eighty-five samples of soils, collected in different parts of the state, are being subjected to complete chemical analysis, both the total and acid soluble constituents being determined. In connection with this work crops grown under different treatments are being analyzed. This work is bringing out the differences in composition between the soils of the limestone and sandstone areas of the State, and is showing that the lack or abundance of phosphorus in the soil is reflected in the crops produced.

COOPERATION

Field experiments. The number of cooperative field experiments being conducted this year is somewhat smaller than in years past, and effort is being made to restrict these experiments to such as may receive personal attention in the field and may also be part of some specific investigation which is being conducted either by this department or some other department of the Station. Material has been supplied for such experiments with corn, alfalfa, grasses, soybeans, potatoes and other crops, and a few fertilizer experiments have been started.

County fair exhibits. The legislature has made provision for putting a third exhibit on the road during the fair season, and through the courtesy of the Fair Managers Association, good shipping routes, reaching largely into counties in which the exhibit has not previously been shown, have been worked out for each of the three exhibits. The State Railroad Commission has kindly arranged with the railroads for a uniform rating for the shipment of the exhibit. In order to assist in advertising it, a descriptive, illustrated circular has been issued, which will be supplied to fair associations as needed.

Farm management investigations. The advancing price of land and labor make it increasingly important that close attention be given to the business methods of the farm. The Station is making a study of the systems of rotation and general management that are being practiced throughout the state, including the several sub-divisions of farm work, such as dairying, poultry keeping, etc. About 80 dairymen and 100 poultrymen are now cooperating with the Station in this work. On a smaller number of farms all the

enterprises that enter into their operation are being studied in cooperation with the office of Farm Management Investigations of the Bureau of Plant Industry, U. S. Department of Agriculture.

Statistics of crop production. The necessary foundation on which to build a better system of management is the knowledge of what is now being done. To obtain this knowledge statistics of crop production in the state are collected annually by the township assessors. Thus far these statistics have been buried in the annual reports of the Departments of State and Agriculture. The Station has arranged the statistics of some of the principal crops of the State for 1908 and 1909 in such a manner as to show the centers of chief production in the State, and has arranged with the U. S. Bureau of Census for a tabulation by townships of Ohio's corn crop, in order that comparison may be made with the statistics collected by the township assessors.

FORESTRY

Forest work at the Station. At Wooster the Forestry Department has a nursery containing about 225,000 seedling trees. About 125,000 catalpa, 50,000 locust, and 20,000 white ash seedlings will be propagated this spring. Aside from this about 15 pounds of white pine seed has been sown and about 100,000 seedlings may be expected, providing the season is favorable. There are about 10,000 ornamental trees in the nursery rows which will be tested under various conditions in different parts of the State.

Three native woodlots at the Station farm are being reconstructed and considerable planting and improvement work will be done this spring and next. Different kinds of trees will be used and different distances of planting and different mixtures of trees will be tested. Every forest tree which gives promise of some value and seems adapted to the site will be tried out. In one of the woodlots both practical and aesthetic forestry will be practiced. That is, useful forest trees will be planted and yet combined and grouped in such a manner as to produce both practical and aesthetic results.

Several woodlots are also being reafforested at the Southeastern Test-farm, but a serious loss has been suffered here through fire started from the railroad.

Cooperative forestry. From the nature of the work the greater part of its forestry operations must be carried on away from the Station. Cooperative work consists of two kinds: first, with farmers, and second, with state and municipal institutions. The latter, in most cases, is more satisfactory, because it insures greater permanency than the former. Cooperative work with the farmers and land owners will be continued, but efforts will be directed towards the

care of the native woodlots in preference to the planting of groves and plantations. So much interest has been aroused in the latter case, especially where locust and catalpa were used, that it seems justifiable to restrict the giving out of these species to cases where good opportunities present themselves for demonstration or experimentation, or to localities where little interest has been manifested in the past. It seems advisable to offer every inducement possible in the way of furnishing different kinds of trees for wooodlot improvement. The increase of interest in woodlot management is apparent. Out of 208 applicants for help in forestry work, 73 were for aid in managing woodlots, being double the number for the previous year. Work among the land owners in southern Ohio will be pushed as far as time and funds permit. Some of the iron and coal companies have applied for help in managing their lands. A map of the land of the Carbondale Coal Company, in Athens county, was partially prepared last summer, and will be completed this year. Plans for operation will accompany the map.

The experimental planting of pine and locust for the purpose of reclaiming eroded waste lands is of the utmost importance, and work will be conducted along this line. The locust is especially well adapted for this purpose, on a small scale, because of its value for post timbers, its adaptability to the conditions, and its propensity to aid in the establishment of blue-grass sod.

Forestry at public institutions. The Experiment Station is now conducting forestry work on the cooperative plan at seven state and municipal institutions, and at one private institution. These are: The State Reformatory, Mansfield; The Tuberculosis Hospital, Mt. Vernon; The Boys' Industrial School, Lancaster; Miami University, Oxford; The Hospital for the Criminal Insane, Lima; The University of Cincinnati, Cincinnati; Oberlin Water Works Farm, Oberlin; Kenyon College, Gambier. Work will be carried on with each institution this year. The lands of these institutions represent almost every soil and and topographical condition in Ohio, and practically every one offers excellent opportunities for different phases of forestry work. Opportunity is offered for the management of second growth forest and the reconstruction of old woodlots and for plantation plantings. One of the most important experiments now going on is the planting on the Oberlin Water Works Farm of 100 acres, to protect the intake of the reservoir. A considerable number of white pines were planted on this farm this spring and the work will be contined in the future.

Forest survey. The department has employed six men for the summer to assist in preparing maps and working plans for the various state institutions where work is being carried on. As far as time permits, the work will be extended to the more promising tracts of the companies and individuals where work can be done.

Studies of commercial trees will also be conducted. The study of the chestnut will be completed and the results published.

HORTICULTURE AND ENTOMOLOGY

Revival of apple culture in Ohio. For several seasons these departments of the Station have been working in cooperation with orchardists in various sections of the State, with the result that it has been convincingly demonstrated that it is possible to bring back many an abandoned orchard into very profitable production, and it is no longer a question that many a hill farm in southeastern Ohio, which is now affording its owner but a meager subsistence, might be made to yield an income rivalling those obtained from the more level lands of the State, if planted in apples and properly cared for.

NUTRITION

The work of this department, which is being conducted under the Adams Fund, has included investigations on (1) the nutritive values of the various compounds of phosphorus in foods; (2) the separation of the various groups of phosphorus compounds in foodstuffs, and (3) the effects of conditions of growth on the mineral nutrients in blue-grass.

Plans have been completed for the construction of a building for slaughter, refrigeration and metabolism experiments, appropriations for which purpose, amounting to $22,000, have been made by the last two General Assemblies. This building is to be of brick, 40x60 feet on the ground, with two stories and a basement. The first floor is devoted to slaughter and refrigeration work, the coolers occupying 18x38 feet and providing for temperatures from zero to 40 degrees Fahrenheit. The second floor will contain an animal experiment room 23x39 feet in size and four smaller accessory rooms for various experimental operations.

The character of the work of this department is illustrated by the three bulletins issued during the year, Numbers 207, 213 and 215. In Bulletin 207 it is shown that the specific or characteristic effects of foods are influenced in important ways by the ratio of the inorganic acids to the inorganic bases which they contain. A ration which contains a fair proportion of fruits, vegetables, milk or roughage, is likely to furnish a sufficient amount of the bases (sodium, potassium and calcium) in relation to the acids (sulphur, phosphorus and chlorine); but a ration made up of little else than the cereal foods, eggs and meat, is liable to be deficient in the base and to contain an excess of the acids.

In Bulletin 213, which was published jointly with the Experiment Station of the University of Missouri, a comparison of a considerable number of balanced rations shows that the muscular growth produced was generally in accord with the content of the foods in organic phosphorus compounds. As a food for growing animals it is shown that corn is deficient in protein, calcium and phosphorus, also in basic minerals as compared with acid minerals, and further, is characterized by an excess of magnesium in relation to calcium. The effects of these conditions, as exhibited by the growth of pigs, are a retarded development of proteid aud bony tissues and an over-development of fatty tissue. Such animals reach their limit of growth prematurely and their breeding capacity is impaired by the lessened circulation of blood in the reproductive organs, due to the pressure of an excess of internal fat.

In Bulletin 215 new methods are published to supplant very imperfect ones for distinguishing between organic phosphorus, which contributes to the growth of all the tissues of the body, and inorganic phosphorus, which contributes only to the growth of bones.

These studies of the nutritive values of phosphorus compounds are showing that glycerophosphates are more useful than the other organic and inorganic compounds found in foods. The content of farm foods of phosphorus in this condition is very small, and it seems probable that the results of these experiments will show that under certain conditions of practice it will pay to add glycerphosphates to the food just as we use common salt.

It will be seen from the foregoing summary that the work of this department is being directed toward some of the fundamental problems in the nutrition, both of the lower animals and of man.

SOIL INVESTIGATIONS

These investigations have been continued without interruption at the main station and at the three test-farms, and work has been begun on the Findlay and Boardman test-fields. The work at the main station includes field experiments, pot-cultural studies in the greenhouse and analyses of soils and crops in the chemical laboratory. In these pot-cultural and chemical investigations a large number of soils from the different soil formations of the State are being studied, and while useful information is being obtained through these methods they do not and probably never can take the place of the field experiment.

In the chemical laboratory improved methods of investigation are being developed which are making it possible to determine in a general way the condition of a particular soil, but the more accurate

knowledge which is essential to the most economical management of the land is only to be obtained in the field itself, and only through investigations comprehensive in plan and continued through many years.

The work which has thus far been accomplished in this direction gives very great encouragement to the expectation that it will ultimately be possible to outline a system of treatment for a particular soil which will give the highest results in economy of production, but to accomplish this end it will be necessary to know the geological history of the soil, its chemical and physical constitution and the treatment to which it has been subjected for a considerable period of years. Neither of these factors can be omitted from the computation, but if either is more important than the others it is probably the first and the last.

For this reason it is useless to send a sample of soil to the Experiment Station for examination unless the sample be accompanied by information respecting its location and previous treatment, and before the Experiment Station can have that thorough knowledge of the soil formations of the State which is essential to accuracy in advice it must have more of these formations under field investigation.

COUNTY EXPERIMENT FARMS

In another part of this report is given the text of the law enacted last winter which authorizes the establishment of county experiment farms. Should there be any considerable number of such farms established under this law it will be possible to materially extend our knowledge of the soils of the State, for the first work undertaken on such a farm should be the study of its soil. To the end that this study may be of the greatest value to the county as a whole the farm should be located upon a soil typical of as large an area of the the county as possible, except in some cases where in adjoining counties it may be better to locate the experiment farms on different soil types, even though one of these types may represent a smaller area than the other.

WHAT THE COUNTY EXPERIMENT FARMS MAY ACCOMPLISH

The Experiment Station was located in Wayne county in 1892, on a soil representing the average soils of the county in geological origin and in present condition, though somewhat below the averge in natural fertility. The Station at once instituted a series of experiments on this soil, which were so planned as to bring out the comparative effect of different kinds and quantities of fertilizing materials and manures, a part of the land being left continuously without treatment for comparison. The outcome of this work is, that in a

rotation of corn, oats and wheat, one year each, followed by clover and timothy two years, the crops produced have had an average annual value for the last five years of $12.66 per acre, computing corn at half a dollar per bushel, oats at one-third of a dollar, wheat at one dollar and hay at eight dollars per ton, on land that has had no fertilizing or manuring. The use on the corn, oats and wheat of a complete chemical fertilizer, costing $23.50 for each rotation, or $4.70 annually, has increased the annual value of the produce to $20 per acre. When the rotation has been reduced to four years, by omitting the timothy crop, and ten tons of barnyard manure, reintorced with phosphate rock and followed by a ton of lime per acre has been applied to the corn crop, and 400 pounds per acre of complete commercial fertilizer has been applied to the wheat, the cost of treatment, in addition to the manuring, amounting to $14.00 for each 4-year rotation, or $3.50 annually, the average annual value of the produce has amounted to more than $30 per acre on forty acres of land.

This last result has been accomplished by applying to large-field culture the lessons taught by the small-plot experimiments, and the outcome is a larger yield, produced at a less cost than any that has been secured in the plot work.

This study of the maintenance and increase of the produce of the land should be the leading work of the county experiment farms, for the Station's work on its several test farms has shown that the results attained on the Wooster soil cannot be accepted as an assurance that similar results will follow similar methods on other soils. For example, the same application of chemical fertilizers which has given increase to the value of $50 at Wooster has increased the produce by only $28 at the Strongsville Test-farm, while at the Germantown Test-farm the rate of increase, during the first six years of the work, has been greater than that at Wooster during the corresponding period.

Next to the study of the soil will come investigations on the adaptability of different varieties of grains and forage crops to the different sections of the State, and on different methods of culture. In some sections, also, studies will be made of certain crops which are not adapted to the soils of the State in general; for example, of the sugarbeet in northwestern Ohio.

As these county farms will be branches of the main station, their work will be coordinated with that of the Station, thus systematizing the work throughout the State and bringing to each county the direct assistance of the specialists employed at the main station and of the results being attained at all the other county stations.

Of course the chemical, physical and bacteriological laboratories, with their costly equipment, will remain at the main station, and such questions as require their facilities for solution will be carried to them.

PUBLICATIONS

The following publications have been issued during the year:

Bulletin 206, pp. 1-21. The maintenance of fertility: Field experiments with fertilizers and manures on tobacco, corn, wheat and clover in the Miami Valley. By C. E. Thorne.

Bulletin 207, pp. 23-52. The balance between inorganic acids and bases in animal nutrition. By E. B. Forbes.

*Bulletin 208, pp. 53-70. Protection of fruit trees from rodents. By F. H. Ballou.

*Bulletin 209, pp. 71-89. Rations for fattening swine. By B. E. Carmichael.

*Bulletin 210, pp. 91-167. The blade-blight of oats. By Thos. F. Manns.

*Bulletin 211, pp. 169-212. Third annual report on forest conditions in Ohio. By C. E. Thorne, W. J. Green and Edmund Secrest.

*Bulletin 212, pp. 213-236. Corn judging: Studies of prominent ear-characters in their relation to yield. By C. G. Williams and F. A. Welton.

*Bulletin 213, pp. 237-305. Specific effects of rations on the development of swine. By E. B. Forbes.

*Bulletin 214, pp. 307-456. A brief handbook of the diseases of cultivated plants. (A revision of Bulletin 121). By A. D. Selby.

*Bulletin 215, pp. 457-489. Methods for the quantitative estimation of inorganic phosphorus in vegetable and animal substances. By E. B. Forbes, A. Lehmann, R. C. Collison and A. C. Whittier.

*Bulletin 216, pp. 491-526. Spraying machinery. By W. H. Goodwin.

*Bulletin 217, pp. 527-559. Apple culture in Ohio. By F. H. Ballou.

*Bulletin 218, pp. 561-603. I. The Status of the potato industry in Ohio. By F. H. Ballou. II. Seasonal notes on potatoes. By J. H. Gourley.

*Bulletin 219, pp. 605-639. The relative durability of post timbers. By. W. J. Green and J. J. Crumley.

*Bulletin 220, pp. 641-673. Annual report, meteorological summary, press bulletins and index.

*Circular 96, October 1, 1909, 36 pp. Essentials of successful field experimentation. By C. E. Thorne.

*Circular 97, January 20, 1910, 8 pp. The work of the department of cooperative experiments. By L. H. Goddard.

*Circular 98, February 1, 1910, 18 pp. Minor items of farm equipment. By L. H. Goddard and L. W. Ellis.

*Circular 99, March 1, 1910, 8 pp. Cooperative dairy work. By. L. H. Goddard and M. O. Bugby.

*Circular 100, April 7, 1910, 15 pp. The centers of agricultural production in Ohio. By L. H. Goddard.

*Circular 101, May 12, 1910, 15 pp. Illustrative exhibits at state and county fairs. By L. H. Goddard and W. A. Lloyd.

*Circular 102, May 20, 1910, 7 pp. Spraying to kill weeds. Some useful methods. By A. D. Selby.

The publications marked (*) have been sent to the entire mailing list of the Station. The other numbers have been published in small editions and sent only to special lists of names, but a few copies are still available for distribution to those who may request them.

Eleven press bulletins have been issued during the year, Nos. 304 to 314 inclusive. These are republished with the present report.

PERSONNEL

Messrs. L. T. Bowser and L. L. Scott, assistants in the departments of chemistry and entomology, have resigned their positions to accept other situations. Mr. Thos. F. Manns has been transferred to the department of Soils as Soil Bacteriologist, and the following new appointments have been made: Albert G. Woods and E. G. Arzberger, B. S., Assistant Botanists; R. D. Whitmarsh, B. S., Assistant Entomologist; and George Boltz, B. S., Assistant Chemist.

Respectfully submitted,

CHAS. E. THORNE, Diretor.

APPENDIX

Bulletins

OF THE

Ohio Agricultural Experiment Station.

1909-1910

CONTENTS.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 220 JULY, 1910

METEOROLOGICAL SUMMARY—PRESS BULLETINS—INDEX.

METEOROLOGICAL SUMMARY FOR 1909.

BY C. A. PATTON.

EXPLANATION OF TABLES.

The following tables contain statistics of temperature, rainfall, etc., for the year, and are compiled from data obtained from daily observations. T stands for "trace"—less than .01 inch of rainfall. Temperature is given in degrees Fahrenheit.

Table I shows the daily rainfall at the station during the year in inches and hundredths.

Table II shows the daily mean temperature for each day of 1909 and the monthly mean temperature with the 22 years' average.

Table III giver the monthly mean temperature at the station with the 22 years' average for the same.

Table IV gives the monthly mean rainfall for the station with the 22 years' average for ahe same.

Table V gives the monthly mean temperature for the state for 1909 with the 22 years' average.

Table VI gives the monthly mean rainfail for 1909 with the 22 years' average for the state.

Table VII gives the monthly mean temperature and rainfall for the station and state for 1909 with the 22 years' average.

Table VIII contains the mean temperature, the highest and lowest temperatures, with the range of temperature for each month; the number of clear, fair and cloudy days; the rainfall, snowfall and prevailing direction of wind, for both the station and state for 1909.

Table IX contains the principal points of interest on temperature, rainfall, and state of weather at the station during the year, and a grand summary for twenty-two years.

Table X contains the principal points of interest on temperature, rainfall, and state of weather for the state during the year and a grand summary for twenty-seven years.

Table XI gives the highest and lowest temperature for each month during the past twenty-two years, for both the station and state.

NOTES ON THE WEATHER AT THE STATION, 1909.

SUMMARY BY MONTHS.

LATITUDE 40° 47′ 01″, LONGITUDE 81° 55′ 48″.

ELEVATION ABOVE THE SEA 1,030 FEET.

JANUARY.

The mean temperature for January was 31.7°, which is 4.3° above the station average for January. The highest, 66°, occurred on the 24th; the lowest, 11°, on the 13th. Cloudy weather prevailed. Rain or snow fell on twelve days. The total precipitation was 2.95 inches, which is .21 inch below the station average for January. The prevailing wind was southwest.

FEBRUARY.

The mean temperature for February was 33.6°, which is 7.1° above the station average for February. The highest, 60°, occurred on the 24th; the lowest, —2°, on the first. Cloudy weather prevailed. Rain or snow fell on seventeen days. The total precipitation was 5.22 inches, which is 2.36 inches above the station average for February. The prevailing wind was southwest.

MARCH.

The mean temperature for March was 35.9°, which is 1.3° above the station average for March. The highest, 60°, occurred on the 9th; the lowest, 12°, on the 17th. Cloudy weather prevailed. Rain or snow fell on sixteen days. The total precipitation was 3.02 inches, which is .52 inch below the station average for March. The prevailing wind was northwest.

APRIL.

The mean temperature for April was 48.4°, which is .4°, above the station average for April. The highest, 81° occurred on the 18th; the lowest, 13° on the 10th. Cloudy weather prevailed. Rain or snow fell on twelve days. The total precipitation was 3.92 inches which is 1.10 inches above the station average for April. The prevailing wind was southwest.

MAY.

The mean temperature for May was 57.9° which is .5° below the station average for May. The highest, 84° occurred on the 31st; the lowest, 31° on the 11th. Fair weather prevailed. Rain fell on twelve days. The total precipitation was 4.06 inches, which is .04 inch above the station average for may. The prevailing wind was north.

JUNE.

The mean temperature for June was 69.3° which is 1.6° below the station average for June. The highest, 89° occurred on June 27th; the lowest, 42° on the 19th. Rainy weather prevailed. Rain fell on seventeen days. The total precipitation was 6.44 inches, which is 2.28 inches above the station average for June. The prevailing wind was northeast.

JULY.

The mean temperature for July was 69.6° which is 1.6° below the station average for July. The highest, 89° occurred on the 12th; the lowest, 45° on the 4th. Clear weather prevailed. Rain fell on eleven days. The total precipitation was 4.05 inches, which is .25 inch below the station average for July. The prevailing wind was south and northeast.

AUGUST

The mean temperature for August was 70.4° which is 1.1° above the station average for August. The highest, 89° occurred on the 8th; the lowest, 41° on the 22nd. Clear weather prevailed. Rain fell on ten days. The total precipitation was 5.21 inches, which is 1.83 inches above the station average for August. The prevailing wind was south.

SEPTEMBER.

The mean temperature for September was 62.2° which is 1.6° below the station average for September. The highest, 90° occured on the 14th; the lowest, 30° on the 28th. Clear weather prevailed. Rain fell on seven days. The total precipitation was 1.73 inches, which is 1.44 inches below the station average for September. The prevailing wind was northeast and southwest.

OCTOBER.

The mean temperature for October was 47.8° which is 3.1° below the station average for October. The highest 81.° occurred on the 9th; the lowest, 22° on the 29th. Cloudy weather prevailed. Rain or snow fell on six days. The total precipitation was 2.16 inches which is .12 inch below the station average for October. The prevailing wind was northeast.

NOVEMBER.

The mean temperature for November was 48.3° which is 8° above the station average for november. The highest, 72° occurred on the 13th; the lowest, 21° on the 24th. Cloudy weather prevailed. Rain or snow fell on ten days. The total precipitation was 2.91 inches which is .08 inch above the station average for November. The prevailing wind was south.

DECEMBER.

The mean temperrture for December was 25.2° which is 5.3° below the station average for December. The highest, 66° occurred on the 5th; the lowest—6° on the 30th. Cloudy weather prevailed. Rain or snow fell on fourteen days. The total precipitation was 2.55 inches which is .08 inch below the station average for December. The prevailing wind was southwest.

METEOROLOGY—TABLE I—RAINFALL

DAILY RAINFALL AND MELTED SNOW FOR 1909 AT EXPERIMENT STATION

Date	January	February	March	April	May	June	July	August	September	October	November	December	Date
1	T	......	.05	......	T	.70	.05	......	......	......	.05	......	1
2	......	......	T	......	T	......	......	......	......	......	.34	......	2
3	.14	......	.22	.16	.09	.95	......	......	.10	......	.02	......	3
4	.14	......	.25	.06	.03	.15	......	......	.35	......	......	.02	4
5	.30	.30	......	......	......	......	......	.32	......	......	......	......	5
6	T	.15	T	.75	......	......	......	......	......	......	.19	.06	6
7	T	......	.30	.04	......	.08	......	......	......	......	......	.32	7
8	......	......	......	......	......	.23	......	......	......	......	.32	T	8
9	T	.48	.72	.05	.50	.13	......	.02	T	......	......	T	9
10	.13	.08	.05	.17	1.06	.25	......	......	.04	......	......	......	10
11	.10	T	T	......	.02	......	.20	......	......	.50	......	.05	11
12	.40	.05	......	......	......	......	.51	.08	......	.13	T	.20	12
13	.30	.24	......	.18	......	.25	.14	......	......	......	......	.99	13
14	.02	.76	T	T	T	.07	.02	.11	......	......	......	.05	14
15	......	.26	.02	......	.11	......	......	2.09	.80	T	T	......	15
16	.15	.10	.05	......	.24	......	.87	.11	......	T	.52	......	16
17	T	T	.25	......	......	.69	......	......	......	......	.28	......	17
18	......	......	......	......	......	......	.01	.02	......	.16	T	.02	18
19	......	.60	.28	T	......	......	......	......	......	......	T	......	19
20	......	.05	......	.08	.45	......	......	T	......	......	......	......	20
21	......	.05	......	.40	.60	.57	......	......	......	.20	.33	.10	21
22	T	......	......	T	......	.34	.13	......	T	......	.49	T	22
23	.53	1.16	......	......	......	.16	.18	......	.21	1.02	.37	.02	23
24	......	.74	.22	......	......	.04	T	......	.08	.15	......	.02	24
25	......	.10	.46	......	......	.02	......	......	......	......	......	.50	25
26	......	......	.01	......	......	......	......	.70	......	T	......	T	26
27	......	T	.02	.28	.51	1.71	.24	......	......	......	......	.10	27
28	......	.10	......	......	......	.10	......	1.72	......	......	......	.10	28
29	.34	......	.10	1.03	......	......	1.70	.04	T	......	......	T	29
30	.40	......	.02	.72	.03	......	......	......	.15	......	......	......	30
31	T	......	......	......	.42	......	T	......	......	......	......	......	31
Totals	2.95	5.22	3.02	3.92	4.06	6.44	4.05	5.21	1.73	2.16	2.91	2.55	
Averages	.095	.186	0.97	.130	.131	.215	.131	.168	.058	.070	.097	.082	

METEOROLOGY—TABLE II—TEMPERATURE

MEAN TEMPERATURE FOR EACH DAY OF 1909 AT THE STATION.

Date	January	February	March	April	May	June	July	August	September	October	November	December	Date
1	21.0	9.0	33.0	38.5	47.5	71.5	72.0	73.0	59.0	49.0	57.5	49.5	1
2	27.0	25.5	39.5	43.5	44.5	64.5	71.5	72.5	55.0	47.5	55.0	40.5	2
3	39.5	33.0	35.0	40.0	43.5	67.0	66.5	72.5	61.5	50.0	45.0	38.0	3
4	45.0	40.5	27.5	41.5	44.5	73.5	58.0	70.0	63.5	49.5	45.5	44.5	4
5	43.5	50.5	26.5	57.5	57.5	68.5	64.0	73.5	61.5	53.5	40.0	53.0	5
6	25.0	42.0	41.0	61.5	72.0	66.0	70.5	71.5	55.0	54.0	46.0	39.5	6
7	14.0	31.5	43.0	53.5	64.0	69.0	66.5	71.5	58.5	56.5	51.5	34.5	7
8	21.0	34.0	36.0	43.5	53.5	64.5	67.0	77.5	63.5	57.5	54.0	19.5	8
9	31.5	36.5	48.5	35.0	68.0	69.5	69.5	76.0	67.5	59.5	46.5	8.5	9
10	40.0	33.0	44.0	22.0	49.5	68.5	72.5	68.5	72.0	65.0	54.0	17.0	10
11	33.5	23.5	31.5	34.5	44.5	64.5	73.5	66.0	66.5	54.5	59.5	21.5	11
12	12.5	37.0	33.5	56.0	50.0	61.5	77.5	68.5	66.5	43.0	58.0	31.0	12
13	4.5	37.5	40.0	52.0	60.0	70.0	74.0	73.0	72.5	38.0	61.0	38.5	13
14	29.5	41.5	34.5	39.5	67.0	70.5	72.5	73.0	76.0	46.5	61.5	31.5	14
15	33.5	29.5	32.0	41.5	73.0	62.5	75.5	74.0	71.5	40.5	53.5	29.0	15
16	25.0	21.5	31.0	56.0	63.0	63.0	71.5	74.5	63.0	42.0	51.0	24.0	16
17	26.0	21.5	22.5	62.5	58.0	66.0	67.0	69.5	61.5	42.0	45.0	25.5	17
18	19.5	32.0	29.0	64.5	53.5	56.0	67.0	67.0	61.0	42.5	42.5	19.5	18
19	22.0	43.0	43.5	57.5	54.0	59.5	59.5	70.5	67.0	38.5	39.5	12.5	19
20	31.0	37.0	38.0	42.0	57.0	66.0	63.0	67.0	72.0	46.0	50.0	15.0	20
21	39.5	33.5	34.0	57.0	55.5	74.5	71.5	61.0	67.5	59.0	47.0	20.5	21
22	53.0	37.5	30.0	50.5	57.5	74.5	73.5	60.0	73.5	53.5	57.0	16.0	22
23	54.0	45.5	33.0	43.5	53.0	77.0	64.5	63.5	65.0	42.0	49.0	19.0	23
24	61.5	46.0	39.0	52.0	55.0	77.0	64.0	70.0	58.0	36.5	31.0	18.5	24
25	48.0	25.5	40.0	54.0	56.5	74.5	66.5	76.0	53.0	38.0	31.0	24.5	25
26	34.0	32.5	35.0	45.0	65.0	76.0	68.5	77.0	48.0	49.5	38.8	25.5	26
27	36.5	35.5	43.0	51.0	69.0	79.0	70.5	76.0	50.0	49.0	45.0	19.0	27
28	38.0	26.0	39.5	40.5	59.0	77.5	75.5	74.0	47.5	39.0	52.0	15.5	28
29	35.0	......	38.0	54.5	65.0	76.0	77.0	72.0	59.5	35.0	45.5	10.0	29
30	24.5	......	36.5	61.0	63.5	70.5	77.5	61.0	49.5	51.0	35.5	4.0	30
31	14.5	......	37.5	......	71.5	......	71.0	61.0	......	55.0	......	18.5	31
Monthly mean	31.7	33.6	35.9	48.4	57.9	69.3	69.6	70.4	62.2	47.8	48.3	25.2	
22-year ave.	27.4	26.5	37.2	48.0	58.4	67.7	71.2	69.3	63.8	50.9	40.3	30.5	

METEOROLOGY—TABLE III

MONTHLY MEAN TEMPERATURE FOR TWENTY-TWO YEARS AT WOOSTER.

Temperature in degrees Fahrenheit.

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Date
1888..........	23.0	28.8	31.7	46.3	57.7	68.9	70.1	67.8	57.1	44.9	40.7	31.4	47.3	1888
1889..........	31.1	22.9	38.7	47.1	57.8	64.5	70.0	66.0	60.8	45.3	39.3	40.7	48.6	1889
1890..........	36.0	36.6	30.9	48.4	56.0	69.8	70.5	65.8	59.6	50.0	41.3	28.8	49.5	1890
1891..........	30.0	34.0	32.0	49.0	52.0	68.0	68.0	71.0	68.0	49.0	38.0	37.0	49.6	1891
1892..........	22.0	33.0	33.0	47.0	57.0	70.0	70.0	69.0	61.0	49.0	38.0	28.0	48.0	1892
1893..........	18.0	28.0	38.0	50.1	57.6	69.3	72.0	67.9	63.2	52.3	37.7	30.9	48.7	1893
1894..........	32.8	26.7	43.5	50.5	57.5	67.9	71.4	69.2	66.1	52.3	36.5	32.9	50.6	1894
1895..........	21.9	17.9	32.4	49.5	59.4	69.9	68.6	70.9	66.5	44.2	40.4	32.8	47.8	1895
1896..........	27.9	29.2	29.8	54.6	64.5	65.6	70.2	68.5	60.6	45.8	44.4	30.6	49.3	1896
1897..........	24.0	30.0	39.3	47.2	53.4	64.3	73.2	67.0	66.7	55.9	40.7	31.8	49.4	1897
1898..........	31.6	27.4	43.3	45.3	58.2	68.7	74.5	71.1	66.2	52.6	38.4	27,9	50.4	1898
1899..........	26.6	21.3	35 0	52.1	60.0	69.4	70.0	71.0	61.6	55.0	43.2	29.0	49.5	1899
1900..........	30.2	25.0	31.8	47.8	61.5	68.5	72.6	74.0	67.1	58.9	40.6	30.7	50.7	1900
1901..........	28.3	20.0	39.1	45.2	57.9	69.1	75.9	71.6	63.3	51.7	36.6	26.1	48.7	1901
1902..........	26 3	21.4	41.2	46.2	61.2	65.6	73.0	66.4	62.7	53.9	47.3	28.7	49.5	1902
1903..........	24.4	29.0	45.7	48.0	62.2	63.0	71.8	68.8	64.4	58.2	36.8	21.7	49.1	1903
1904..........	18 6	20.5	37.6	42.8	59.4	67.0	69.8	66.7	64.2	50.4	39.6	28.1	47.1	1904
1905..........	22.6	19.8	41.2	46.8	59.2	68.0	71.6	70.0	63.8	51.0	38.3	33.1	48.8	1905
1906..........	35.9	25.8	30.2	51.9	59.9	68.8	71.0	74.2	67.7	51.4	40.4	31.2	50.7	1906
1907..........	30.8	24.6	44.9	41.7	52.8	64.6	69.9	68.6	65.0	47.4	38.5	32.1	48.4	1907
1908..........	28.7	26.8	43.1	50.1	62.2	68.1	72.4	69.0	66.4	53.0	41.0	31.7	51.0	1908
1909..........	31.7	33.6	35.9	48.4	57.9	69.3	69.6	70.4	62.2	47.8	48.3	25.2	50.0	1909
Average.....	27.4	26.5	37.2	48.0	58.4	67.7	71.2	69.3	63.8	50.9	40.3	30.5	49.3	

METEOROLOGY—TABLE IV

MONTHLY RAINFALL FOR TWENTY-TWO YEARS AT WOOSTER

Rainfall—Inches

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Date
1888........	3.52	2.43	3.34	2.48	3.82	2.31	4.54	4.35	1.92	3.18	4.96	1.39	3.18	1888
1889........	4.33	2.42	2.13	1.58	2.97	4.86	6.73	1.98	4.06	1.36	3.53	3.93	3.32	1889
1890........	4.71	6.20	4.37	3.10	6.01	5.57	2.67	4.66	5.12	7.45	2.61	1.74	4.51	1890
1891........	2.74	4.83	3.71	1.66	2.24	7.13	3.28	1.95	0.94	1.33	5.73	2.92	3.20	1891
1892........	2.67	2.67	3.38	2.44	7.69	7.89	4.73	2.69	3.20	0.37	2.06	1.74	3.46	1892
1893........	4.01	6.33	1.89	5.66	6.28	2.51	1.38	1.53	1.85	5.18	2.49	1.50	3.38	1893
1894........	2.19	3.37	2.36	1.74	4.41	2.23	1.38	0.76	4.07	2.53	2.41	3.15	2.55	1894
1895........	3.92	1.00	1.98	1.69	1.38	4.20	2.19	2.30	3.92	1.15	4.21	3.51	2.65	1895
1896........	1.73	2.27	3.67	3.34	3.41	3.98	8.05	1.96	5.16	0.71	1.78	2.41	3.21	1896
1897........	2.82	2.64	2.81	2.75	4.97	2.98	3.89	3.86	0.29	0.89	5.76	2.50	3.01	1897
1898........	4.10	2.27	6.44	2.56	4.60	2.70	6.79	5.53	2.15	4.25	4.14	2.29	3.99	1898
1899........	3.29	1.64	3.95	1.28	4.42	1.95	3.73	0.53	5.56	2.21	1.59	2.78	2.74	1899
1900........	2.78	2.74	2.25	1.70	2.23	3.71	5.65	5.97	2.19	2.10	4.30	0 99	3.05	1900
1901........	1.58	1.20	3.09	2.46	4.32	4.82	3.32	3.58	5.64	0.81	1.62	3.47	2.99	1901
1902.......	0.63	0.83	2.99	1.46	2.57	5.55	5.26	1.87	3.49	1.52	2.62	4.07	2.74	1902
1903........	3.54	3.69	3.29	4.55	1.59	3.69	4.61	6.58	2.07	2.63	2.25	1.95	3.37	1903
1904........	5.27	3.90	6.22	6.59	4.45	1.67	4.93	2.03	2.27	0.87	0.40	2.68	3.44	1904
1905........	1.83	1.36	2.61	2.51	5.97	7.50	5.14	4.47	5.10	2.32	2.04	2.08	3.58	1905
1906........	1.93	1.06	3.57	2.27	2.98	3.81	4.93	7.38	5.16	3.55	2.39	3.77	3.57	1906
1907........	6.92	1.09	5.80	2.69	3.48	3.81	3.96	2.04	3.13	2.34	1.33	3.41	3.33	1907
1908........	1.96	3.89	5.02	3.64	4.56	2.17	3.44	3.17	0.73	1.22	1.0 9 1	3.05	2.83	1908
1909........	2.95	5.22	3.02	3.92	4.06	6.44	4.05	5.21	1.73	2.16	2.9	2.55	3.68	1909
Average ...	3.16	2.86	3.54	2.82	4.02	4.16	4.30	3.38	3.17	2.28	2.83	2.63	3.26	

METEOROLOGY—TABLE V

MONTHLY MEAN TEMPERATURE FOR TWENTY-TWO YEARS FOR THE STATE

Temperature in degrees Fahrenheight

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Date
1888.........	24.3	30.5	34.2	49.2	59.1	70.4	72.1	70.4	60.3	47.9	42.9	33.3	49.5	1888
1889..........	33.3	25.8	40.2	49.9	60.2	66.7	72.5	69.1	62.9	47.9	41.0	43.8	51.1	1889
1890..........	38.8	39.4	34.5	51.3	59.2	73.3	73.1	68.8	62.1	52.7	43.9	31.2	52.3	1890
1891..........	33.0	36.0	35.0	52.0	58.0	71.0	69.0	70.0	67.0	51.0	40.0	39.0	51.7	1891
1892..........	24.0	35.0	35.0	49.0	59.0	73.0	73.0	71.0	64.0	52.0	38.0	29.0	50.1	1892
1893..........	18.0	29.0	38.0	50.2	58.3	70.6	74.5	70.7	65.2	53.7	39.3	32.7	51.6	1893
1894..........	37.7	28.9	45.1	50.6	60.0	71.3	74.3	71.2	67.8	53.9	37.5	33.9	52.3	1894
1895..........	23.4	19.6	35.5	51.7	61.1	70.2	71.6	73.5	69.0	46.9	41.3	33.9	49.9	1895
1896..........	29.4	30.5	32.4	56.7	67.9	69.5	73.2	71.8	62.7	49.0	45.1	32.9	51.7	1896
1897..........	25.5	32.4	41.5	49.3	46.3	68.1	75.5	69.4	66.9	58.1	42.2	32.8	50.6	1897
1898..........	32.4	30.0	45.0	47.2	61.0	71.9	76.0	73.5	67.8	53.1	38.8	28.8	52.1	1898
1899..........	27.8	21.6	36.9	53.3	63.3	71.5	74.1	73.7	64.1	57.4	43.9	30.2	51.5	1899
1900..........	31.1	26.0	32.9	50.1	62.9	69.8	74.1	76.3	69.3	60.5	41.6	31.6	52.3	1900
1901	29.2	21.1	39.5	46.7	59.0	70.9	78.1	73.1	64.8	53.8	37.7	27.9	50.2	1901
1902...... ...	27.3	22.3	41.9	48.2	62.6	66.9	74.0	67.4	63.6	54.6	48.5	29.4	50.5	1902
1903..........	27.1	29.9	46.7	49.9	63.9	64.4	72.9	70 7	65.6	54.0	37.2	23.4	50.5	1903
1904..........	20.7	22.9	39.7	44.4	60.7	68.4	71.4	68.8	65.5	52.2	40.5	28.6	48.6	1904
1905..........	22.7	20.8	42.7	48.5	60.7	69.2	73.0	71.7	65.3	52.6	39.6	32.9	50.0	1905
1906..........	35.7	27.3	31.3	52.1	61.3	69.8	72.1	74.6	68.9	52.7	41.1	32.3	51.6	1906
1907..........	32.2	27.7	45.9	42.5	54.5	65.6	72.6	69.5	65.5	48.8	39.1	33.0	49.6	1907
1908..........	29.1	26.0	45.4	51.0	62.8	69.2	73.9	71.2	68.0	54.1	41.7	33.1	52.1	1908
1909..........	32.2	34.7	37.3	49.1	58.7	70.1	66.4	72.1	63.7	49.1	49.4	26.1	50.7	1909
Average	28.9	28.1	38.8	49.7	60.0	69.6	73.1	71.3	65.5	52.5	41.4	31.8	50.9	

METEOROLOGY—TABLE VI

MONTHLY RAINFALL FOR TWENTY-TWO YEARS FOR THE STATE

Rainfall—Inches

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Date
1888........	3.65	1.74	3.55	1.99	3.77	3.41	4.40	5.16	2.27	3.98	4.25	1.47	3.30	1888
1889	3 13	1.35	1.50	1.79	3.71	4.13	4.25	1.50	3.62	1.78	4.02	2.81	2.79	1889
1890........	4.94	5.25	5.29	3.15	5.52	4.50	1.99	4.70	5.56	4.27	2.53	2.37	4.17	1890
1891........	2.82	4.91	4.19	2.13	2.20	4.82	3.82	3.07	1.50	1.76	5.00	2.39	3.21	1891
1892........	2.05	3.27	2.16	2.63	4.63	6.73	3.13	6.15	1.27	0·67	2.62	1.85	3.09	1892
1893........	2.56	5.13	2.09	6.37	4.97	3.34	2.49	2.17	1.57	4.24	2.09	2.61	3.30	1893
1894........	2.14	2.79	2.16	2.31	4.00	2.65	1.56	1.67	3.31	2.01	2.17	2.98	2.47	1894
1895........	4.00	0.69	1.59	2.11	1.80	2.44	2.00	2.96	1.66	1.22	4.11	3.85	2.37	1895
1896........	1.67	2.25	3.34	2.78	2.67	4.81	8 11	3.38	5.13	1.20	2.63	1.65	3.29	1896
1897........	1.93	3.64	5.17	3.27	3.93	2.85	4.65	2.72	0.78	0.64	6.62	2.39	3.21	1897
1898..... ..	5.25	2.32	6.23	2.38	4.10	2.86	3.98	4.50	2.56	3.72	3.17	2.71	3.65	1898
1899........	3.01	2.11	4.66	1.68	4.32	2.96	4.18	1 82	2.69	2.14	1.72	3.16	2.87	1899
1900...	2.37	3.53	2.35	1.89	2.40	2.99	4.62	3.68	1.76	1.89	4.15	1.24	2.74	1900
1901........	1.70	1.24	2.66	3.40	3.96	4.38	2.73	3.32	2.86	0.73	1.54	3.79	2.69	1901
1902........	1.42	0.88	2.76	2.21	3.09	7.48	4.69	1.67	4.55	2.28	2.60	3.95	3.13	1902
1903........	2.36	4.95	3.51	4.01	2.82	3.97	3.67	3.20	1.52	2.62	2 10	2.07	3.07	1903
1904........	3.85	2.69	5.73	2.64	3.79	2.88	4.13	2.74	1.95	1.50	0.37	3.09	2 95	1904
1905........	1.73	1.58	2.50	3.10	5.63	4.72	3.93	4.46	2.86	3.63	2.63	2.25	3.25	1905
1906........	1.98	1.16	3.97	1.89	2.17	3 41	5.14	4.77	2.92	3.19	2.59	3.68	3.07	1906
1907........	6·11	0.85	5.55	2.74	3.47	4.57	5.36	2.48	3.92	2.76	1.93	3.16	3.57	1907
1908........	1.82	4.10	2.43	3.69	4.72	2.52	4.08	2.59	0.58	1.17	1.06	2.33	2.84	1908
1909........	3.24	5.39	2.77	4.13	4.72	5.86	3.90	3.68	1.56	2.46	1.93	2.68	3.53	1909
Average...	2.90	2.81	3.60	2.83	3.74	4.01	3.95	3.29	2.56	2.27	2.81	2.66	3.12	

METEOROLOGY—TABLE VII.

MEAN TEMPERATURE AND RAINFALL FOR THE STATION AND STATE FOR 1909 AND FOR TWENTY-TWO YEARS.

Temperature in degrees Fahrenheit. Rainfall in inches.

	January	February	March	April	May	June	July	August	September	October	November	December	Year
Mean temperature at the Station, 1909	31.7	33.6	35.9	48.4	57.9	69.3	69.6	70.4	62.2	47.8	48.3	25.2	50.0
Twenty-two years' average temperature at the Station	27.4	26.5	37.2	48.0	58.4	67.7	71.2	69.3	63.8	50.9	40.3	30.5	49.3
Mean temperature for the State, 1909	32.2	34.7	37.3	49.1	56.7	70.1	66.4	72.1	63.7	49.1	49.4	26.1	50.7
Twenty-two years' average temperature for the State	28.9	28.1	38.8	49.7	60.0	69.6	73.1	71.3	65.5	52.5	41.4	31.8	50.9
Rainfall at the Station 1909	2.95	5.22	3.02	3.92	4.06	6.44	4.05	5.21	1.73	2.16	2.91	2.55	3.65
Twenty-two years' average rainfall at the Station	3.16	2.86	3.54	2.82	4.02	4.16	4.30	3.38	3.17	2.28	2.83	2.63	3.26
Rainfall for the State 1909	3.24	5.39	2.77	4.13	4.72	5.86	3.90	3.68	1.56	2.46	1.93	2.68	3.53
Twenty-two years average rainfall for the State	2.90	2.81	3.60	2.83	3.74	4.01	3.95	3.29	2.56	2.77	2.81	2.66	3.12

METEOROLOGY—TABLE VIII.
SUMMARY BY MONTHS.

	Temperature											Number of days				Precipitation in inches			
AT THE STATION	Mean	Highest	Date	Lowest	Date	Range	Mean daily range	Greatest daily range	Date	Least daily range	Date	Clear	Fair	Cloudy	Rainfall .01 in. or more	Monthly rainfall	Average daily rainfall	Monthly snowfall	Prevailing wind
January	31.7	66	24	—11	13	77	16.3	38	28	6	*16	1	5	25	12	2.96	.095	15.00	S. W.
February	33.6	60	24	—2	1	62	18.7	31	26	5	5	3	5	20	17	5.22	.186	5.25	S. W.
March	35.9	60	9	12	17	48	18.4	30	18	7	*4	5	6	20	16	3.02	.097	7.75	N. W.
April	48.4	81	18	13	10	68	24.6	37	29	8	20	7	3	20	12	3.92	.130	5.75	S. W.
May	57.9	84	31	31	*11	53	24.0	43	8	11	21	8	14	9	12	4.06	.131	....	N
June	69.3	89	27	42	19	47	21.6	38	20	13	5	12	7	11	17	6.44	.215	....	N. E.
July	69.6	89	*12	45	4	44	23.7	35	9	11	23	18	10	3	11	4.06	.131	....	S&N E
August	70.4	89	*8	41	22	48	23.7	39	23	12	18	21	8	2	10	5.21	.168	....	S.
September	62.2	90	14	30	28	60	24.3	35	28	9	5	17	5	8	7	1.73	.058	....	NE&S W
October	47.8	81	*9	22	29	59	24.8	43	9	5	24	13	5	13	6	2.16	.070	.25	N. E.
November	48.3	72	*13	21	24	51	20.6	36	*23	7	9	6	5	19	10	2.91	.097	.50	S.
December	25.2	66	5	—6	30	72	15.8	35	6	3	14	3	3	25	14	2.55	.082	9.75	S. W.
Sums and averages	50.0	77	..	20	..	57.4	21.4	36.7	..	8	..	114	76	175	144	3.68	.122	44.25	S. W.
FOR THE STATE																			
January	32.2	74	24	—17	13	91		49	12			6	7	18	13	3.24	.105	14.60	S. W.
February	34.7	70	23	—17	1	87		42	1			8	7	13	12	5.39	.192	5.10	S. W.
March	37.3	70	19	6	17	64		39	24			9	9	13	11	2.77	.069	3.60	N. W.
April	49.1	90	18	13	13	77		52	29			9	11	10	11	4.13	.138	1.00	S. W.
May	58.7	91	31	24	2	67		51	5			12	10	9	12	4.72	.152	.10	S. W.
June	70.1	96	27	36	16	60		48	20			10	12	8	15	5.86	.195	....	S. W.
July	66.4	97	30	40	*5	57		46	..			14	11	7	10	3.90	.126	....	S. W.
August	72.1	96	*9	35	*22	61		52	..			18	10	4	8	3.68	.119	....	W.
September	63.7	94	13	25	28	69		45	..			16	8	6	6	1.56	.062	....	N.
October	49.1	86	*9	16	29	70		52	..			15	8	8	7	2.46	.079	T	S. W.
November	49.4	80	*14	15	24	65		50	..			12	9	10	8	1.93	.064	.28	S. W.
December	26.1	75	*5	—20	30	95		51	..			8	8	15	11	2.68	.086	10.20	S. W.
Sums and averages	50.7	85	..	13	..	71.9		48	..			137	110	121	124	3.53	.116	34.88	S. W.

*On other dates also.

METEOROLOGY—TABLE IX.

SUMMARY BY YEARS AND GRAND SUMMARY FOR TWENTY-TWO YEARS AT WOOSTER.

	1888	1889	1890	1891	1892	1893	1894	1895
AT	WOOSTER					EXPERIMENT STATION		
Mean temperature	47.3°	48.6°	49.5°	49.6°	48.°	48.7°	50.6°	47.8°
Highest temperature	....	91.5° *1	94.5° Aug. 3	99.° Aug. 8	98.° July 25	96.° *5	98.° July 19	98.° June 4
Lowest temperature	—5° Feb. 9	—5° *2	1.° Mar. 2	0.° Mar. 1	—20° Jan. 20	—9.° Jan. 11	—7.° Dec. 28	—6.° *8
Range of temperature	....	96.5°	93.5°	99.°	118.°	104.°	105.°	104.°
Mean daily range of temperature	....	18.7°	18.9°	21.°	19.°	20.2°	22.9°	21.8°
Greatest daily range of temperature	....	42° Apr. 23	41.° Jan. 13	42° Sept. 23	46.° July 17	45.° Aug. 9	45.° July 31	55.° Oct. 6
Least daily range of temperature	....	2° Jan. 6	4.5° *3	4.° Feb. 8	4.° *4	3.° *6	4.° *7	1.° Nov. 22
Number of clear days	....	125	109	116	116	96	127	125
Number of fair days	....	103	119	110	123	164	154	117
Number of cloudy days	....	137	137	125	98	105	84	123
Number of days rain fell	....	119	149	119	119	129	130	102
Total yearly rainfall	38.23 inches	39.87 inches	54.21 inches	38.36 Inches	41.46 inches	40.61 inches	30.60 inches	31.45 inches
Greatest monthly rainfall	4.51 inches	6.73 in. July	7.45 in. Oct.	4.26 in. June	7.89 in. June	6.33 in. Feb.	4.41 in. May	4.21 in. Nov.
Least monthly rainfall	1.39 inches	1.36 in. Oct.	1.74 in. Dec.	1.96 in. April	1.37 in. Oct .	1.38 in. July	0.76 in. Aug.	1.00 in. Feb.
Prevailing direction of wind	S.	S.	S.	S.	S. W.	S. W.	S. W.	W.

*1 July 10 and Sept. 1. *2 Feb. 23 and 24. *3 Jan. 8 and Sept. 10. *4 March 5, Nov. 1, 3 and 25, Dec. 1 and 18. *5 July 7, 25 and Sept. 7. *6 Jan. 24, Feb. 11 May 26. *7 Dec. 1 and 21.

METEOROLOGY—TABLE IX. Continued.

SUMMARY BY YEARS AND GRAND SUMMARY FOR TWENTY-TWO YEARS AT WOOSTER.

	1896	1897	1898	1899	1900	1901	1902	1903
	EXPERIMENT STATION							
Mean temperature	49.6°	49.4°	50.4°	49.5°	50.7°	48.7°	49.5°	49.1°
Highest temperature	93.° Aug. 9	96.° *10	96.° July 3	95.° Aug. 20	95.° July 4	95° *12	97.° May 4	94.° *14
Lowest temperature	—6° Feb. 19	—18° Jan. 26	—9° Feb. 2	—21° Feb. 10	—10° Feb. 27	—11° Dec. 21	—9° Feb. 5	—9.° Feb. 19
Range of temperature	99.°	114.°	105.°	116.°	105.°	106.°	106.°	103.°
Mean daily range of temperature	19.°	21.5°	20.3°	22.9°	20.6°	20.1°	21.3°	21.6°
Greatest daily range of temperature	43.° May 8	49.° Oct. 5	50.° Nov. 14	52.° Oct. 24	43.° May 6	43.° April 30	45 May 4	48.° Nov. 8
Least daily range of temperature	3.° *9	0.° Feb. 6	5.° *11	3.° Feb. 18	2.° Nov. 20	2.° April 20	4. *13	3.° *15
Number of clear days	130	124	133	126	149	152	183	148
Number of fair days	106	123	104	114	68	66	49	58
Number of cloudy days	130	115	128	125	118	147	133	159
Number of days rain fell	134	123	134	116	132	142	140	121
Total yearly rainfall	38.47 inches	36.16 inches	47.85 inches	32.93 inches	36.61 inches	35.91 inches	32.86 inches	40.44 inches
Greatest monthly rainfall	8.05 in. July	5.76 in. Nov.	6.79 in. July	5.56 in. Nov.	5.97 in. Nov.	5.64 in. Nov	5.55 in. June	6.58 in. Aug.
Least monthly rainfall	0.71 in. Oct.	0.29 in. Sept.	2.15 in. Sept.	0.53 in. Aug.	0.99 in. Dec.	0.81 in. Oct.	0.63 in. Jan.	1.59 in. May
Prevailing direction of wind	S. W.	S. W.	N. W.	N. S. W.	S. W.	S. W.	S. W.	S. W.

*8 Jan. 12, 13 and Feb. 5. *9 Jan. 10 and March 8. *10 July 5 and 6. *11 Jan. 21, March 2 and Dec. 18. *12 July 1, 22 and 28.

METEOROLOGY—TABLE IX—Concluded.

SUMMARY BY YEARS AND GRAND SUMMARY FOR TWENTY-TWO YEARS AT WOOSTER.

AT	1904	1905	1906	1907	1908	1909	Summary for twenty-two years
	EXPERIMENT STATION						
Mean temperature	47.1°	49.°	50.6°	48.4°	51.0°	50.0°	49.3°
Highest temperature	92° July 17	92.° July 17	92.° June 29	90.° Aug. 12	95.° *17	90.° Sept. 14	99.° Aug. 8 '91
Lowest temperature	—21.° Jan. 5	—12. Feb. 14	—14.° Feb. 7	—14° Jan. 27	—3° Feb. 9	—11 Jan. 13	—21 *19
Range of temperature	113.°	104.°	106.°	104.°	98.°	101°	120°
Mean daily range of temperature	21.5°	20.8°	20.6°	20.8°	23.°	21.4°	20.8°
Greatest daily range of temperature	48.° Dec. 28	42.° *16	40.° April 18	42.° Jan. 20	49.° Sept. 18	43° *18	55.° Oct. 6 '95
Least daily range of temperature	0.° Dec. 25	2.° Dec. 18	2.° Jan. 18	4.° Aug. 6	5.° Dec. 13	3.° Dec. 14	0.° *20
Number of clear days	149	144	130	109	141	114	131
Number of fair days	47	44	60	58	78	76	92
Number of cloudy days	170	177	175	198	147	175	134
Number of days rain fell	136	118	142	138	117	144	129
Total yearly rainfall	41.28 inches	42.93 inches	42.80 inches	40.00 inches	33.94 inches	44.22 inches	39.14 inches
Greatest monthly rainfall	6.59 in. April	7.50 in. June	7.38 in. Aug.	6.92 in. Jan.	5.02 in. Mar.	6.44 in. Jan.	8.05 in. July 1896
Least monthly rainfall	0.40 in. Nov.	1.36 in. Feb.	1.06 in. Feb.	1.09 in. Feb.	0.73 in. Sept.	1.73 in. Sept.	.29 in. Sept. 1897
Prevailing direction of wind	S. W.	S.	S.	N. S. W.	S. W.	S. W.	S. W.

*13 Jan. 22 and April 28. *14 July 4 and 9. *15 Jan. 4, Nov. 27 and Dec. 6. *16 April 9 and May 2. *17 Aug. 3, Sept. 24 and 25. *18 May 8 and Oct. 9. *19 Feb. 10 1899 and Jan. 5, 1904. *20 Feb. 6, 1897 and Dec. 25. 1904.

METEOROLOGY—TABLE X.

SUMMARY BY YEARS AND GRAND SUNMARY FOR TWENTY-SEVEN YEARS FOR THE STATE.

FOR THE STATE.	1883	1884	1885	1886	1887	1888	1889
Mean temperature	49.4°	50.6°	48.0°	49.6°	51.4°	49.5°	51.1°
Highest temperature	98.° Aug. 22	98.° *1	101.° July 21	98.6° July 7	108.° July 18	102.° Aug 3	99.5° Aug. 31
Lowest temperature	—17.2° Jan. 22	—34.° Jan. 25	—31.5° Jan. 29	—21.5° Jan. 12	—21.° Jan. 7	—15.° Jan. 27	—13.5° Feb. 24
Range of temperature	115.5°	133.°	132.°	120.1°	29.°	117.°	113.°
Greatest daily range of temperature	55.2° Mar. 18	50.° *2	58.5° Jan. 30	57.° Dec. 11	57.° Dec. 11	50.°	53.° Mar. 30
Average numder of days rain fell	146	145	148	131	121	125	118
Mean yearly rainfall	44.98 inches	40.19 inches	30.08 inches	36.71 inches	33.63 inches	39.64 inch	33.53 inches
Mean daily rainfall	.123 inch	.110 inch	.104 inch	.100 inch	.092 inch	.108 inch	.092 inch
Prevailing direction of wind	S. W	S. W	S. W	S. W	S. W	S. W	S. W
	1890	**1891**	**1892**	**1893**	**1894**	**1895**	**1896**
Mean temperature	52.4°	52.0°	50.0°	50.1°	52.4°	49.9°	51.8°
Highest temperature	103.1° Aug. 3	101.° Aug. 10	103.° July 25	102.° July 19	105.° *4	106.° July 20	103.° Apr. 17
Lowest temperature	—4.° Mar. 7	—8.° Mar. 2	—25.° Jan. 20	—24° Jan. 11	—27.° Dec. 29	—24.° Feb. 6	—18.° *6
Range of temperature	107.1°	109.°	128.°	126.°	132.°	130.°	121.°
Greatest daily range of temperature	48.5° Apr. 11	50.° *3	51.° Sept. 25	54.6°	60.° Oct. 19	59.° *5	53.° Mar. 25
Average number of days rain fell	149	120	121	113	100	89	124
Mean yearly rainfall	50.33 inches	38.61 inches	37.16 inches	39.63 inches	29.75 inches	28.46 inches	39.58 inches
Msan daily rainfall	.138 inch	.060 inch	.102 inch	.108 inch	.081 inch	.070 inch	.108 inch
Prevailing direction of wind	S. W	S. W	S. W	S. W	S. W	S. W	S. W

*1 Sept. 28 and Oct. 1. *2 Sept. 5 and Dec. 4. *3 April 27 and 30. *4 July 18 and 19. *5 Jan. 15 and March 29. *6 Feb. 20 and 21.

METEOROLOGY—TABLE X.—Concluded.

SUMMARY BY YEARS AND GRAND SUMMARY FOR TWENTY-SEVEN YEARS FOR THE STATE.

FOR THE STATE.	1897	1898	1899	1900	1901	1902	1903
Mean temperature	50.6°	52.°	51.5°	52.°	50.2°	50.6°	50.5°
Highest temperature	113.° July 4	105.° July 1	105.° Sept. 6	103.° *8	109.° July 22	100.° July 8	104.° July 25
Lowest temperature	—27° Jan. 26	—20.° Feb. 3	—39.° Fep. 10	—20.° *9	—20.° Feb. 23	—17.° Feb. 14	—20.° Feb. 19
Range of temperature	140.°	125.°	144.°	123.°	129.°	117.°	124.°
Greatest daily range of temperature	67.° *7	....	....	57.° Feb. 9	61.° Dec. 14	56.° May 4	60.° Sept. 25
Average number of days rain fell	110	121	107	107	107	114	111
Mean yearly rainfall	38.54 inches	43.78 inches	34.51 inches	32.87 inches	32.98 inches	37.58 inches	39.87 inches
Mean daily rainfall	.105 inch	.119 inch	.094 inch	.090 inch	.090 inch	.103 inch	.109 inch
Prevailing direction of wind	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.

	1904	1905	1906	1907	1908	1909	Summary for 27 years
Mean temperature	48.6°	50.0°	51.6°	49.6°	52.1°	50.7°	50.7°
Highest temperature	99.° *10	100.° July 10	101.° Aug. 21	98.° July 22	104.° Aug. 3	97.° July 30	113.° July 4-97
Lowest temperature	—30.° Jan. 4	—20.° Feb. 3	—23.° Feb. 6	—19.° Feb. 6	—22.° Feb. 9	—20° Dec. 30	—39.° Feb. 10 99
Range of temperature	129.°	120.°	124.°	117.°	126.°	117.°	152.°
Greatest daily range of temperature	54.° Jan. 5	57.° May 24	54.° Oct. 13	57.* Feb. 13	60.* Oct. 5	51.°	67.° Sept. 1897
Average number of days rain fell	117	118	124	129	111	124	120
Mean yearly rainfall	35.36 inches	39.02 inches	36.87 inches	42.90 inches	34.09 inches	42.32 inches	37.52 inches
Mean daily rainfall	.096 inch	.107 inch	.101 inch	.117 inch	.092 inch	.116 inch	.101 inch
Prevailing direction of wind	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.

*7 Sept. 25 and 26. *8 July 4, Aug. 6 and 10. *9 Jan. 20 and Feb. 27. *10 July 17 and Sept. 29.

METEOROLOGY—TABLE XI.

MONTHLY MAXIMUM AND MINIMUM TEMPERATURE FOR TWENTY-TWO YEARS—FOR WOOSTER.

Date	January		February		March		April		May		June		July		August		September		October		November		December	
	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest
1888	..	−5	..	−1	..	8	..	19	..	31	..	42	..	43	..	41	..	31	..	27	..	21	..	9
1889	54	12	54	−5	71	16	80	21	90	30	87	38	92	49	90	45	92	37	76	23	65	16	65	18
1890	66	5	65	14	60	1	74	23	83	30	88	46	94	45	95	40	88	38	81	30	66	24	48	15
1891	51	12	60	3	61	0	83	21	82	28	89	44	89	49	99	53	98	42	88	25	71	10	58	16
1892	54	−20	54	6	65	10	76	28	86	38	90	56	98	48	92	49	88	36	81	25	67	16	61	−2
1863	51	−9	47	−2	75	10	83	24	84	36	92	45	95	47	93	37	95	28	85	24	66	15	62	6
1894	56	1	64	−1	75	14	92	24	83	35	93	37	98	41	96	41	93	36	80	28	65	31	57	−7
1895	54	−6	60	−6	59	9	80	21	94	27	98	35	92	42	94	42	93	34	73	19	72	18	61	−2
1896	53	−2	58	−6	65	4	89	19	86	44	87	39	92	45	93	41	92	34	71	21	69	13	56	1
1897	61	−18	54	0	69	11	79	21	78	31	88	37	96	50	92	42	96	28	86	25	65	12	60	2
1898	64	−1	64	−9	71	12	77	16	81	32	90	40	96	45	90	46	90	38	86	24	66	13	56	1
1899	55	−6	57	−21	67	9	86	21	86	30	92	40	94	45	95	39	94	32	92	22	66	22	63	−2
1900	54	−5	65	−10	57	−4	78	20	89	25	90	44	95	44	94	49	89	41	86	30	69	6	55	11
1901	53	−4	40	0	69	−1	82	22	82	33	91	38	95	50	94	47	86	34	79	26	67	18	64	−11
1902	47	2	59	−9	69	9	83	24	97	29	89	39	93	46	88	40	85	32	77	27	72	24	60	−5
1903	60	−8	63	−9	76	21	74	19	89	27	88	41	94	42	92	43	89	32	79	26	71	9	49	−2
1904	60	−21	57	−10	74	13	72	12	88	33	88	44	92	46	90	42	89	31	83	19	68	15	63	−1
1905	59	−8	43	−12	79	10	77	23	82	31	89	38	92	50	90	46	87	36	80	23	61	16	52	13
1906	72	6	65	−14	61	−5	80	21	86	29	92	47	88	46	91	48	90	44	74	22	72	23	58	6
1907	67	−14	50	−5	82	12	78	15	81	29	89	40	88	40	90	43	88	34	82	22	65	18	56	9
1908	51	4	56	−3	75	21	80	24	89	30	91	36	92	46	95	43	95	28	84	24	68	17	59	7
1909	66	−11	60	−2	60	12	81	13	84	31	89	42	89	45	89	41	90	30	81	22	72	21	66	−6
Extremes	72	−21	65	−21	82	−5	92	12	97	25	98	35	98	40	99	37	98	28	92	19	72	6	66	−11

METEOROLOGICAL—TABLE XI.—Concluded.

MONTHLY MAXIMUM AND MINIMUM TEMPERATURE FOR TWENTY-TWO YEARS FOR THE STATE.

Date	January		February		March		April		May		June		July		August		September		October		November		December	
	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest
1888	68	−15	69	−10	77	−6	92	19	91	23	102	34	97	42	102	35	92	26	80	22	81	17	63	1
1889	61	1	70	−14	82	10	88	15	96	26	92	38	98	47	100	40	99	28	83	17	77	9	73	10
1890	75	1	73	1	69	−4	86	20	92	28	101	39	101	43	103	40	92	33	85	29	77	17	65	3
1891	65	3	80	−2	74	−5	95	15	93	25	98	40	95	41	101	39	99	36	93	20	76	0	66	9
1892	61	−25	74	1	80	6	90	14	99	28	101	47	103	40	99	45	96	34	89	20	76	8	70	−12
1893	63	−24	68	−14	87	−8	93	20	94	23	102	40	101	42	101	37	100	24	95	15	76	1	72	−5
1894	66	−16	76	−15	91	3	97	16	98	31	102	29	105	36	104	36	103	27	90	15	79	4	70	−27
1895	62	−19	70	−24	86	−7	90	16	102	19	105	29	106	34	103	31	105	25	84	8	85	5	79	−13
1896	70	−4	78	−18	73	−7	103	15	99	36	98	23	102	39	102	35	100	25	85	17	79	7	67	−15
1897	71	−27	72	−9	82	5	92	11	91	25	102	31	113	44	101	38	105	25	97	20	76	8	71	−7
1898	71	−18	72	−20	84	5	87	10	92	29	99	39	105	38	100	40	102	38	96	20	76	2	67	−18
1899	66	−15	67	−39	76	0	94	6	96	28	102	36	105	41	104	39	107	26	94	20	79	18	69	−7
1900	67	−20	80	−20	70	−9	87	15	97	20	96	38	103	38	103	40	100	33	93	23	80	..	65	−2
1901	67	−10	60	−20	84	−8	91	18	90	26	103	30	109	48	101	42	98	29	88	20	79	10	73	−19
1902	63	−11	66	−17	82	−4	90	17	98	24	98	33	100	43	97	37	94	24	88	21	87	17	63	−11
1903	73	−13	69	−20	85	11	88	10	93	22	95	35	104	42	101	38	98	26	93	15	88	2	57	−11
1904	70	−30	75	−18	86	−1	81	7	95	27	98	37	99	41	97	38	99	23	92	15	75	0	69	−16
1905	65	−17	54	−20	85	−5	89	12	93	26	99	34	100	44	96	41	95	30	89	20	71	10	58	2
1906	79	−14	72	−23	74	−12	91	18	94	24	100	34	98	43	101	43	98	36	91	18	82	14	68	−15
1907	75	−23	66	−19	96	−2	86	10	89	24	96	36	98	37	96	40	93	29	88	19	71	11	69	2
1908	69	−8	66	−22	85	12	91	16	96	25	100	33	102	42	104	37	100	23	90	15	77	5	68	−2
1909	74	−17	70	−17	70	6	90	13	91	24	96	36	97	40	96	35	94	25	96	16	80	15	75	−20
Extremes	79	−30	80	−39	96	−12	103	6	102	19	105	29	113	34	104	31	107	23	97	8	88	0	79	−27

PRESS BULLETINS

The following press bulletins have been issued during the year:

No. 304. July 5, 1909. HARVEST MITES, "JIGGERS" OR "CHIGGERS."

Last year, threshermen, harvest hands, workers in potteries, and apparently all classes of laborers who were obliged to handle straw in any way suffered intensely from the attacks of harvest mites or "jiggers." Horses, stabled under mows in which infested straw had been stored, were in many cases rendered frantic by the irritation caused by these minute insects. Weather conditions lately have been exceedingly favorable for the development of a similar or worse plague this season.

The young mites are of microscopic size, blood red in color and belong in the order of spiders. The immature larvae are provided with only six legs while the adults have eight. It is the larval forms which cause annoyance. "Jiggers" are abundant in bramble thickets and on low growth in woods and along streams. They often occur in immense numbers in grain straw, sometimes causing sickness, and even death has sometimes resulted directly or indirectly from their attacks.

The eggs are laid on the ground. The young, upon hatching, in the species which have been studied, attach themselves to insect hosts and draw their sustenance from these for a time, dropping off when full fed. It is probably a misjudged attempt to follow their usual habit of parasitism that induces them to burrow into the flesh of human beings and warm blooded animals, a proceeding which invariably results in their death.

Preventives and remedies: The Ohio Experiment Station recommends that so far as possible one should avoid sitting or lying in locations that are apt to be infested. Where exposure is unavoidable, dust flowers of sulphur into all the underclothes, especially into the stockings and inside the shoes. Threshermen should sift it into all their clothing and rub it over their bodies. Where infested straw must be stored in mows, dust the floor with sulfur and thoroughly sift it over the first layers of straw placed on the floor. Napthaline powder may be used instead of sulfur and is said to be equally effective, but the odor makes it more objectionable. As soon as possible after quitting work, exposed persons should take a bath in strong soapsuds. The carbolic and tar soaps are very useful for this purpose. If the mites have already penetrated beneath the skin, bathe in a very strong suds of carbolic soap. A very effective wash for this purpose is to make a solution of one of the coal tar sheep dips, such as Zenoleum or Chloronaphtholeum, one part of the dip to a about 100 to 150 parts of water. Other solutions that may be used on the welts are of ammonia, coal oil (kerosene) or ordinary cooking soda. A dilute tincture of iodine or collodion, if lightly applied to the swellings, will protect from the air and allay the smarting sensation. A complete change of clothing should be made after bathing.

No. 305. July 5, 1909. THE MINERAL ELEMENTS IN ANIMAL NUTRITION.

Bulletin 201, Ohio Agricultural Experiment Station, introduces students of agriculture to this important though somewhat unfamiliar subject.

That portion of plants and animals which will not burn, the ash or mineral substance, though slight in amount is exceedingly important. Every part of an animal contains mineral matter as an essential constituent, and every process in the life of animals involves these mineral substances.

The mineral nutrients are as important to the growth of plants as to the animals which use them for food. These minerals come from the soil. The amount and kind of fertility in the soil powerfully influences not only the *amount* but also the *kind* of growth, not only of plants grown upon the soil but also of the animals which use these plants as food.

Our most important stock feeding problem in the central United States is the most profitable use of corn. Corn happens to be particularly poor in mineral nutriment, especially so in calcium, the oxide of which we know as lime. Our most profitable use of corn demands that we consider not only proteid but also mineral supplements. The subject is of greatest importance as it relates to growing or milking animals generally and also to those raised most largely on corn, namely: hogs and poultry.

Many manufactured feeds are deficient in mineral nutrients and even pasture grass may be so deficient in minerals, especially in dry seasons and on certain types of soil, as to cause malnutrition of the bones of stock. The composition of foodstuffs affects the composition of bone, muscle, fat and visceral organs in the growth produced. The laxative character of feeds often depends upon the mineral constituents. Human foods are many of them deficient in minerals. Those human foods most deficient in mineral matter are rice, hominy, bolted cornmeal, patent flour, potatoes, sugar and fat meat. If one makes large use of these he should also use others containing much more mineral nutriment.

This bulletin may be had for the asking by addressing the Experiment Station at Wooster.

No. 306. July 19, 1909. FORAGE CROPS FOR EMERGENCIES.

Considerable areas in Ohio have recently been stricken by severe hail storms greatly injuring, and in some cases destroying the corn and oat crops. Many farmers are asking what may be done to relieve the situation. It is probable that in most instances the corn crop will send out new growth and make more feed than any new seeding would furnish.

While it is getting a little late to harvest a full crop of mid-summer forage crops it is yet worth while to seed the following crops:

Hungarian or Common millet—40 lbs. of seed per acre.
Sorghum—12 lbs. of seed in rows 36 inches apart.
Buckwheat—50 lbs. of seed per acre.
Rape—7 lbs. per acre.
Thick Corn, drilled solid or in rows.

No. 307. October 6, 1909. DO SOUTWESTERN OHIO SOILS NEED LIME?

The correspondence of the Experiment Station indicates that some of the lands in Southwestern Ohio which have been longest in cultivation are in need of lime, notwithstanding the fact that this region is underlaid with limestone.

The first indication of lime-hunger in the soil is the behavior of the clover crop. The seed sown in the spring takes root and apparently a perfect stand is obtained. At harvest the land is fairly evenly covered with young clover, but there are patches, of greater or less extent, in which the plants seem unthrifty. As the season progresses these patches increase in size and the contrast becomes more apparent. By the following spring these patches are bare of clover, and weeds of various kinds, especially horse sorrel, have taken its place.

This unthriftiness of the clover usually makes its first appearance on the higher and dryer lands, and especially on those which have been long in cultivation with scanty manuring. It is also more apparent in dry seasons; in fact in a season of abundant rainfall throughout the summer it may not be observed, but the general tendency is towards an increasing difficulty in securing satisfactory crops of clover.

It should not be confused with complete destruction of the young plants by late spring frosts, nor with a disease of clover which causes a wilting and browning of the leaves and the appearance of black spots on the stems.

The Experiment Station is desirous of obtaining more definite knowledge on this point and to this end the request is made, that parties who may own or know of fields in which the conditions above described have been observed, will communicate with the Station and permit it to take a few bushels of soil for examination in its soil laboratories.

No. 308. November 15, 1909. PURCHASING SEEDS AND FRUIT TREES.

Many inquiries come to the Ohio Experiment Station regarding the best firms of which to buy fruit trees and seeds.

We have no means of knowing which firms are honest and which are not.

Most nurserymen and seedsmen try to keep their stock pure and the varieties true to name, but they often buy of others and mistakes may occur in handling. If nurserymen and seedsmen are to be censured more than other business men for lax methods, it is because they get stock from doubtful sources, by exchange or purchase, and because they so often take the liberty of substituting a variety which is "just as good" for the one ordered. Even if the Station could inspect twice a year the stocks of several hundred firms in the state, who deal in trees and seeds, it would not be possible to determine whether the varieties which are found growing were true to name. Much less would it be possible to arrive at any conclusion as to the results after exchanges have been affected by the dealers and substitutions made, so that orders may be filled.

The Station officials are cognizant of the fact that it is hard to find pure stocks of trees and seeds, for many varieties comes to it wrongly named.

There is no complete remedy for this state of affairs but it is a good plan to learn something of a man's reputation through his neighbors before buying trees of him. Then go early in the season and examine his trees. If an order is given specify that the trees must be of his own growing and that there *must be no substituting*. If ordering from a distant firm select those who advertise in first-class periodicals and specify as before, *no substituting*

No. 309. March 14, 1910. DOES FARM POULTRY PAY?

In January of this year eggs were retailing in Cleveland and in many other cities in Ohio at 55 cents per dozen. During much of the winter they were selling at 40 cents or higher. These prices almost prohibited the use of eggs as an article of food, and caused many consumers to jump at the conclusion that there was easy money in egg production.

Careful inquiry among a number of farmers would seem to indicate that not to exceed 5 percent of the hens were laying at all during these months of high prices, and that, had the producer received for his product the price paid by the consumer, he would still, in many cases, have been a loser. Certain farms reporting to the Ohio Experiment Station, at Wooster, show an egg cost of from 7 to 13 cents each for the month of January. This does not argue that the poultry enterprise on these farms is an unprofitable one as a whole, for the entire year would have to be considered before arriving at a conclusion regarding this; whereas, no data are as yet available for consideration in this connection.

The Experiment Station is, however, conducting an investigation along this line in cooperation with an increasing number of farmers and poultrymen throughout the State and will doubtless secure data which will have a very distinct bearing upon the cost of living. The value of work of this kind can scarcely be overestimated. All accurate information regarding the cost of production will serve to bring the producer and consumer closer together.

No. 310. March 21, 1910. ARE WE GROWING THE BEST VARIETIES OF CORN IN THIS COUNTY?

The Ohio Experiment Station, in cooperation with the Ohio Corn Improvement Association, is making a study of the varieties of corn in Ohio. In 1909 fourteen counties had one or more county or township variety tests. The most of the varieties tested were those which some of the best farmers in that community were growing. The Experiment Station provided seed of some of the other best known varieties. Eighteen of these tests were carried through in such a way that the results are of scientific value.

The average yield of the poorest variety in these tests was 35.4 percent less than the average yield of the best variety. The two poorest varieties in each test averaged 30.2 percent lower than the two best. In eight of the tests the winning variety was a local one. In the other ten an outside variety led the list. In no case, however, was the winning variety from outside the State. Comparing the yield of the local varieties, the poorest was 27.1 percent less than the best.

The average yield of the State in 1909 was 39.5 bushels. The best and the poorest yielding varieties are both represented in this average. This being true, then if all the farmers in the State would grow the best variety, the State yield would surely be increased from 10 to 15 percent. Thirteen and five-tenths percent increase would amount to 5 1-4 bushels per acre or 15,000,000 bushels in total yield.

A large-plot variety test in any locality would be of much value to all the corn growers in that neighborhood. We would call this to the attention of our corn men. If arrangements cannot be made for such a test, then each progressive grower will certainly find it profitable to try at least one good variety in comparison with his own. If in doubt as to methods write to the Experiment Station at Wooster.

No. 311. March 28, 1910. EXAMINE YOUR SEED POTATOES FOR DRY-ROT. DISEASED SEED WILL GROW A DISEASED CROP.

Potatoes in Ohio, both early and late varieties, suffered severly in 1909 from premature dying due to Fusarium blight, which causes dry-rot in the tubers.

The Botanical Department of the Ohio Experiment Station wishes *to warn growers so they may avoid the losses which might otherwise come from planting diseased seed potatoes.* Aside from reduced yield or premature dying last year, every one needs to examine his seed tubers before cutting for planting. If potatoes for cooking are being used from similar stock, then the women of the household will find the disease wherever present.

The disease shows as dark or black spots running through the potato from the stem end. Usually the stem end of the potato, when diseased, will show a sunken appearance around the stem. In any case the dark spots show in the tubers when cut across near the stem end with a knife; in cases of bad infection, the black spots may run half way through the tubers. Where the infection is slight, it may occur only near the stem end. Of course, some of the tubers may be free from spots, and these are safe for planting on new land, but the disease lives over in the soil as well as in the tubers.

Where the disease has not penetrated more than one third of the length of the potato, the half of the potato toward the bud end may be used for seed with better promise. In such cases, the knife used for cutting should be dipped in a solution of corrosive sublimate, formaldehyde or carbolic acid after cutting disesed tubers, and before cutting others.

The point of this warning is to enable growers who have potatoes on hand, *to examine at once and note whether their own seed is safe to plant.* The usual seed treatment for scab, etc., will be very useful to kill dry-rot spores which may adhere to tubers, and may be applied to the healthy portions after separation from the diseased parts of potatoes.

Another reason for advanced warning, is the possible loss to the potato grower who has many bushels of stock on hand. These which show disaese may be used to some advantage in feeding live stock after cooking. They have a fair value in this way for pig feeding.

If seed potatoes are to be bought, it is advisable to secure stock from northern points. Doubtless many northern potato regions have less disease than the more southerly ones. We have found very little in samples received from Red River Valley and from some parts of Michigan. The same may apply to northern New York and northern New England. *In all cases purchasers should examine stock if possible before receiving it.* Any good knife, good light and a careful operator will insure success. Samples of seed tubers sent to the Experiment Station will be examined without charge, reports made to the sender.

No. 312. March 28, 1910. OHIO PASTURES.

Ohio pastures with the woodland, which unfortunately is all more or less pastured, constitutes a portion of the State considerably in excess of the entire cultivated area. The pastures alone cover more than one-third of the entire area of the State. This might aptly be styled the "Neglected One-Third," because throughout the State far less care and attention are given to the maintenance and improvement of the pastures than to any other part of the farm enterprise. In the farm crop section of the State the permanent pasture is made up quite largely of the untillable part of the farm. The "plow" land is considered too valuable for pasture, and yet some data are at hand to show that a well managed pasture in the heart of the corn belt has yielded a net return per acre in excess of that received from corn. From some of the limestone hills of southeastern Ohio cattle that top the market at Pittsburg are finished on bluegrass. During the grazing season 400 lbs. gain per acre for cattle and 600 lbs. for sheep have been reported. If our pasture lands are capable of such returns as this, do they not deserve better treatment?

The Ohio Experiment Station wishes to secure weighing tests of gain per acre from all classes of livestock on pasture, and invites the cooperation of farmers generally in this connection. A little trouble in ascertaining the weights of stock as they go onto grass this spring will be of much interest at selling time. It may help us to put a proper valuation on the pasture land, and it may show the necessity of improving it. The care and management of the pasture—reseeding, cultivation, and fertilizing—are all farm problems in which the Experiment Station is ready to assist the farmer.

No. 313. June 13, 1910. THE BLADE BLIGHT OR YELLOWING OF OATS.

This disease is again prevalent. Its cause is definitely known to be due to a specific bacterium, and its progress is favored by cloudy, rainy weather. The disease begins as small, yellow centers on the blades or as long, marginal lesions occupying one or both edges of the leaf, sometimes yellowing the whole leaf and even extending down the sheath. Often the points of infection are so plentiful as to become confluent, causing a yellow, mottled appearance of the whole leaf. Short periods of sunshine cause the infested areas to turn quickly brown or red.

The amount of loss occasioned by this disease is exceptionally large during certain seasons. In 1907 many of the fields suffered a loss of one-half to two-thirds of the crop, producing oats weighing only 22 to 25 pounds to the bushel. This is explained by the impaired foliage.

Soils which are of high fertility certainly favor the oats and it may possibly pay to stimulate the oats crop with a light dressing of a mixture of one part nitrate of soda with two parts acid phosphate, although this has not been demonstrated. At any rate, the fertilizer will not be lost if the oats is followed by wheat.

As noted in Bulletin 210, of the Ohio Experiment Station, there is considerable difference in the resistance shown by the different varieties. This is again evident in 1910, on the oat variety plots at this Station. The variety "Wide-awake" is very susceptible, while the variety "Sixty Day" and its strains are quite resistant.

Bulletin 210, which treats of this disease, will be sent upon request.

No. 314. June 27, 1910. HOW TO FIGHT THE CHINCH BUG. By H. A. Gossard.

The Ohio Experiment Station sends to all who request it a small package of fungus culture which under favorable circumstances assists in controlling the chinch bug. It cannot be relied on, however, to be of much value in cool, dry weather, and other methods of control are more certain. Chinch bugs are now abundant in many wheat fields and will seriously injure adjacent corn fields as soon as the wheat ripens, unless preventive measures are adopted at the right time. As soon as the weather will permit, after the grain commences to ripen, plow up a strip of ground about ten feet wide around the infested fields, then disk and drag with brush bundles until the soil is pulverized into a fine dust. Now with a short log, from eight inches to one foot in diameter, or with a triangular trough made by nailing two boards together and then weighted with stone, make a furrow by dragging back and forth in the same track until a good ditch has been made across the line of chinch bug march. Where necessary, dress the sides of the furrow with a hoe, making sure that all slopes are even and dusty so that the bugs will be certain to slip back to the bottom of the furrow when they attempt to ascend. With a post-hole digger make holes every

12 to 15 feet in the bottom of the ditch to catch the bugs as they crawl along the bottom. When massed in the holes they may be destroyed by pouring kerosene or kerosene emulsion on them, or a block of wood may be sawed from a post of suitable size and a rod fastened into its center, this being used as a ram to crush the bugs in the holes. If necessary, use the post-hole digger to clean out the dead bugs and keep the holes in order. Owing to rains and use, the dusty sides of the furrow may become passable to the bugs, in which case it may be renewed by dragging the brush bundle through it again, or it may be better to make a new ditch parallel with the old. In case the new ditch is made, the old may be used for a coal tar barrier. The sides of the old furrow should be firmed with a hoe so dust particles will not rattle down on the tar. A slender line of tar should then be strung along the bottom of the furrow, or it may be poured along a line of hardened soil just outside the dust furrow. A water pot with a tubular spout is a good vessel for distributing the tar. The first line will soak into the ground, but soon forms a hardened crust, so that a second line, poured onto the first five or six hours later, will give good results. The tar should be renewed about twice per day during the migrating period of the insects, which usually lasts ten days or two weeks. Post-holes for traps may be dug along the inside of this strip of tar and bugs will be caught notwithstanding wet weather. Dr. Forbes, of the Illinois Station, estimates that a man or boy, giving all his time to guarding the barrier and keeping it in condition, can care for 80 to 150 rods of barrier. The tar will cost about 25 cents per day for a line 100 rods in length.

If by chance or neglect the bugs succeed in reaching the corn, spray the outside rows with kerosene emulsion before the insects spread over the field. Spraying with this material will cost less than $1.00 per acre for ingredients.

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THE COMPOSITION OF WHEAT

OHIO

Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., NOVEMBER, 1910.

BULLETIN 221

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K_2O

AND 1908

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BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 221 NOVEMBER, 1910

THE COMPOSITION OF WHEAT

INFLUENCE OF VARIOUS FACTORS ON THE PHOSPHORUS, POTASSIUM AND NITROGEN CONTENT OF THE WHEAT PLANT.

By J. W. AMES

INTRODUCTION.

The subject of soil fertility is necessarily a broad and complex one. It involves both laboratory and field research. Investigations relating to the physical and biological condition of soils, their chemical composition and reactions are of assistance in the solution of this problem. But it is field experiments, carefully planned and executed, which determine the crop producing capacity and fertilizer requirements of a given soil.

The data here presented are the results of analyses of wheat crops grown on soils on which the fertility investigations of this Station have been conducted for 15 years.

Applications to the soils under experiment, of barnyard manures and chemical fertilizers, in various combinations, have produced results which are becoming more and more valuable.

In order to determine the total amounts of the several essential elements removed from the soil by crop yields it is necessary to know the composition of the crop when harvested. Many analyses of plants have been made by chemists in Europe and America. The results published in the various agricultural works are largely quoted from the work of E. Wolff, and show wide variations in composition, due to soil and climatic conditions.

To secure information which would be accurate for the soils on which the fertility experiments of the Station are being conducted, analyses have been made of the several crops grown on these soils. Owing to the large amount of accumulated data, it has been deemed best to present at this time only that part of the work relating to the composition of the wheat plant.

CROPS ANALYZED

The crops analyzed were sampled from the plots of the 5-year rotation fertilizer tests on the Wooster and Strongsville soils, and from those of the barnyard manure and continuous culture experiments at Wooster. For the years 1907 and 1908, samples of grain and straw were secured from the east and west halves of the Wooster 5-year rotation plots, which have received applications of lime at different times. For the same years samples were taken from the crops grown on the halves of the Strongsville 5-year rotation plots, to which rock phosphate and lime have been applied.

For a complete description of the several fertility experiments the reader is referred to Bulletins 159, 182, 183 and 184, of this Station, by Director Chas. E. Thorne.

The analytical data include the nitrogen, phosphorus and potassium content of the grain and straw* for the different years, as given in detail in the tabulated results.

Especial credit is due to Mr. L. L. LaShell, who assisted in securing samples and made most of the analytical determinations reported.

VARIATIONS IN COMPOSITION

Our analyses of some 200 samples of wheat grain and straw show a considerable variation in their phosphorus, potassium and nitrogen content. The maximum and minimum percentages found, together with an average of all determinations made, are as stated below:

TABLE I—PERCENTAGE COMPOSITION OF WHEAT GRAIN AND STRAW

	Grain			Straw		
	Maximum	Minimum	Average	Maximum	Minimum	Average
	Percent	Percent	Percent	Percent	Percent	Percent
Nitrogen	2.6001	1.4823	1.9750	1.1361	0.2104	0.5280
Phosphorus	0.4841	0.2683	0.3486	0.1148	0.0273	0.0908
Potassium	0.4775	0.2565	0.3547	1.2462	0.4921	0.8304

The differences between the highest and lowest results expressed in percents are approximately uniform for the three constituents in the wheat grain; the results for the straw show greater variations.

VARIATION IN COMPOSITION

	Grain Percent	Straw Percent
Nitrogen	42.99	81.48
Phosphorus	44.58	76.20
Potassium	46.27	60.51

*The straw includes both straw and chaff.

The work of numerous investigators, the most extensive of which is probably that of Lawes and Gilbert,* demonstrates clearly that conditions affecting the development and maturity of a crop are responsible for variation in composition.

The absorption by a plant of an essential mineral element is a physiological process, and depends upon its vital activities. These activities may be affected by any of the conditions which influence crop growth and yields. The principal factors, therefore, which influence variation in composition of the wheat plant may be any one, or a combination of the following conditions: Favorable or unfavorable seasons, composition of the soil, fertilizers applied to the soil, soil moisture, and thickness of stand.

SEASONAL INFLUENCES

Favorable or unfavorable conditions of temperature and moisture influence the proportion of grain to straw, and the deposition of organic matter in the plant. Wheat kernels having a high starch content, which is associated with high yields, contain correspondingly small amounts of total ash and nitrogen.

Lawes and Gilbert state that a season favorable for long and continuous growth after heading produces well-developed kernels and larger yields; that in the better matured grain of favorable seasons, produced under the same conditions of fertilization, there is a lower percentage of potash, phosphorus and nitrogen.

Comparing the phosphorus content of the wheat from Plot 2 in the 5-year rotation at Wooster, which has received phosphorus alone, with the average of the ten unfertilized plots for the years 1904, 1907 and 1908, the results given below show a greater difference in composition due to season than to supply or exhaustion of phosphorus in the soil. The nitrogen results for the ten unfertilized plots and Plot 5, to which nitrogen alone is applied, illustrate further the effect of conditions varying from season to season.

While the amounts of the different constituents of grain and straw, grown under the same conditions of fertilization, vary for the different years, the variation in composition of the crops from plots differently fertilized is relatively the same for most of the years for which we have analytical data.

Aside from the physiological effects of temperature and moisture on the composition of plants, there exists the dissolving action of the rain and dew on the several constituents assimilated during their growth.

*On the composition of the ash of wheat grain and straw. London, 1884.

TABLE II—EFFECT OF SEASON AND PLANT FOOD SUPPLIES ON THE PHOSPHORUS AND NITROGEN CONTENT

Phosphorus content of wheat grain and straw—Percent

Treatment	1904		1907		1908		Maximum variation due to season	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Plot 2, phosphorus	.395	.072	.3839	.0563	.3545	.0364	.0405	.0356
Average of unfertilized plots	.366	.105	.3053	.0548	.3234	.0469	.0607	.0581
Difference due to fertilization	.029	—.033	.0786	.0015	.0311	—.0105	....	....

Nitrogen content of wheat grain—Percent

	1902	1904	1905	1906	1907	1908	Maximum variation in grain due to season
Plot 5, nitrogen	2.532	2.146	2.600	2.400	2.205	2.000	.600
Average of unfertilized plots	2.261	2.086	2.335	2.100	1.918	1.771	.564
Difference due to fertilization	0.271	0.060	0.265	0.300	0.287	0.229	.....

Nitrogen content of wheat straw—Percent

	1902	1904	1907	1908	Maximum variation in straw due to season
Plot 5, Nitrogen	.944	1.056	.602	.580	.476
Average of unfertilized plots	.818	0.947	.488	.444	.503
Difference due to fertilization	.126	0.109	.114	.136	....

Numerous investigators have observed that the composition of plants varies during the different stages of growth; that as plants near maturity they contain smaller amounts of mineral matter and nitrogen than at earlier periods. Wilfarth, Romer and Wimmer,[1] from their work which consisted of elaborate experiments with barley, wheat, peas and potatoes, draw the conclusion that the elements of nutrition which are not stored as reserve material in the tissues of the plant migrate down through the stem and thence to the soil through the roots.

Mulder[2] attributes the variation in composition, found on analyzing a plant at different stages of growth, to the removal of a considerable part of the several constituents by rain.

Johnson[3] states that excess of mineral substance may be deposited upon the surface of leaves and stems and be removed by rain.

[1]On the assimilation of the elements of nutrition by plants during different stages of their growth Landw. Vers., Vol. 63, 1905.

[2]Chemie der Ackerkrume 2, p. 305.

[3]How crops grow, p. 203.

The investigations of Le Clerc and Breazeale,[1] who worked with plants grown under conditions which prevented water from coming in contact with the foliage, furnish data which prove that as the plant approaches maturity the salts move upward toward the living tissues rather than downward through the stems and roots into the soil. They also found that considerable portions of the salts thus deposited were removed by rain.

INFLUENCE OF SOIL AND FERTILIZERS

In this connection may be considered the effect of the deficiency of essential elements of nutrition, and the supply, whether originally present in the soil or furnished by mineral fertilizers and manures. The results of numerous experiments have been reported, which give evidence that the application of fertilizers to depleted soils has increased the relative amounts of the several essential elements removed by various crops.

Lawes and Gilbert's work on the ash of wheat crops, obtained over a period of twenty years from ten differently manured plots, shows that the ash constituents found in the total crop have been increased, but that the amounts stored in the grain are not influenced to any great extent by the quantity taken up, provided this is not deficient.

More recent work can be cited which gives evidence that the composition of crops is influenced by the supply or deficiency of available plant food in the soil. Stutzer[2] found that grain grown in pot culture, with and without addition of phosphorus, contained .297 percent and .375 percent of phosphorus. Chavan,[3] in his work on the influence of phosphorus and potassium on the composition of mixed grasses, grown on soils differently fertilized, obtained the following results:

INFLUENCE OF PHOSPHORUS AND POTASSIUM ON THE COMPOSITION OF WHEAT—PERCENT

Fertilizers applied	Found in the crop					
	Cellulose	Carbohydrates	Ash	Nitrogen	Phosphorus	Potassium
None	25.13	53.08	6.47	1.64	0.11	1.17
Phosphorus	30.50	50.14	6.05	1.42	0.24	1.49
Potassium	29.17	47.94	6.82	1.76	0.10	2.12
Phosphorus and potassium	36.36	42.17	7.21	1.64	0.25	2.16

[1]Plant food removed from plants by rain and dew, Year Book U. S. D. A., 1908, p. 389.

[2]Landwirtschaftliche Versuchsstationen Bd. 65, 1907.

[3]Annuaire agricole de la Suisse 1908, p. 193.

Applications of phosphorus and potassium have increased the amounts of these elements found in the crop. While potassium has increased the nitrogen content, phosphorus has decreased it. The proportion of cellulose increases with the phosphorus content of the crop. This is attributed to the fact that phosphorus hastens the maturing of the crop and produces an increased yield of straw. The addition of phosphorus to the soil has also increased the potassium content of the crop.

Hall, in a paper on "Analysis of the soil by the plant,"[1] which discusses the composition of crops grown at Rothamstead, concludes that the proportions of phosphoric acid and potash in a given plant vary according to the amounts available in the soil, as measured by the response of the crop to applications of phosphoric acid and potash; that these variations are small and often not as great as those due to seasonal conditions.

It has frequently been observed that crops grown on soil lacking in fertility contain larger proportions of total mineral matter than those grown on productive soils. The statement[2] has been made that this indicates that plants grown on such soils are able to assimilate more mineral matter than they can elaborate into plant tissue. A more plausible explanation of this variation is furnished by the data obtained from the analysis of the wheat plant grown on exhausted soil under different conditions of fertilization.

The results show that while wheat grown on the unfertilized plots of the Wooster and Strongsville soils contains a larger percentage of nitrogen and total mineral matter than wheat of good quality from fertilized plots, the addition of nitrogen produces wheat of as good quality and having a higher nitrogen content than that grown on depleted soil, and that the addition of different carriers of phosphorus to the soil increases the yield of grain and the percentage of phosphorus found therein. These results indicate, therefore, that the increased percentage of mineral matter observed in the crop grown on infertile soils is due, not to the fact that the soil furnishes more available plant food than the plant can utilize, but rather to the lack of one or more elements essential to the full development of the plant's organic structure.

COMPARISON OF THE ANALYSES OF SOIL AND WHEAT CROP

The relation between the nitrogen, phosphorus and potassium content of wheat grain and straw grown on the Wooster and Strongsville unfertilized soils; the percentages of total nitrogen, phosphorus

[1]Journal of Agr. Science, Jan., 1905, p. 65.
[2]Soils of the United States; p. 47.

and potassium, and of phosphorus and potassium soluble in N/5 nitric acid found in the soil are given in Table III. In this comparison the results for the same year, 1908, are used to eliminate seasonal variations.

TABLE III—RELATION BETWEEN CONSTITUENTS OF SOIL AND CROP

Soil	In crop			In soil	
	Grain	Straw	Entire plant	Total	Soluble in N/5 nitric acid
Nitrogen—Percent					
Wooster	1.72	0.44	0.890	0.098	...
Strongsville	2.09	0.42	1.076	0.195	..
Phosphorus—Percent					
Wooster	0.3337	0.0507	0.161	0.034	.0003
Strongsville	0.3270	0.0501	0.158	0.047	.0005
Potassium—Percent					
Wooster	0.3605	0.7843	0.678	1.614	.0063
Strongsville	0.4069	1.0264	0.782	1.957	.0163

The total nitrogen content of the Strongsville soil is practically twice that of the Wooster soil; the percentages of total and N/5 nitric acid-soluble phosphorus and potassium are also greater in the Strongsville soil.

The percentages of nitrogen and potassium in the crop are in accord with the amounts found in the soils. A comparison of the amount of the constituents in the crop with those available in the soil, as measured by the increased crop yields obtained from fertilizers on the two soils, shows that the analysis of the crop has given a correct indication of the available nitrogen and potassium supply. Table IV, taken from results contained in Table XVIII of Bulletin 182, by Director C. E. Thorne, gives the total value of increase from the use of phosphorus, nitrogen and potassium alone and in combination on the Wooster and Strongsville soils.

On the Strongsville soil applications of nitrogen and potassium alone, or in combination, have produced only slight increases, which indicates that this soil contains a sufficient supply of both these elements. Phosphorus alone has produced a much greater increase at Strongsville than at Wooster, apparently due to the fact, as stated by Director Thorne in Bulletin 182, "That the phosphorus applied at Strongsville finds already in the soil a supply of available nitrogen and potassium, whereas at Wooster these elements, as well as phosphorus, must be furnished before the full needs of the plant can be met."

TABLE IV—FERTILIZERS ON CROPS GROWN IN 5-YEAR ROTATION, COMPARATIVE VALUE OF INCREASE PER ACRE FOR FIRST TWO ROTATIONS

Plot No.	Fertilizing elements added per acre in total rotation	First rotation		Second rotation	
		Wooster	Strongsville	Wooster	Strongsville
2	Phosphorus, 20 lbs	$8.18	$13.92	$16.39	$21.79
3	Potassium, 108 lbs	5.03	0.67	4.58	0.90
5	Nitrogen, 76 lbs	4.56	0.68	10.19	1.05
6	Phosphorus, 20 lbs Nitrogen, 76 lbs	18.41	17.79	33.66	24.19
8	Phosphorus, 20 lbs Potassium, 108 lbs	13.88	15.52	23.24	18.97
9	Potassium, 108 lbs Nitrogen, 76 lbs	5.67	3.29	10.09	2.59
11	Phosphorus, 20 lbs Potassium, 108 lbs Nitrogen, 76 lbs	25.33	21.84	40.54	23.62
12	Phosphorus, 20 lbs Potassium 108 lbs Nitrogen, 114 lbs	25.04	21.85	43.47	25.17
17	Phosphorus, 30 lbs Potassium, 108 lbs Nitrogen, 38 lbs	......	......	35.07	25.97

The relation between the phosphorus content of the soil and crop is the reverse of that found in the case of the nitrogen and potassium; the percent of phosphorus in the crop, however, is in accord with the previous history of the soils and the increased yields from the use of phosphorus on the Strongsville soil.

The higher nitrogen content of the Strongsville soil may have a bearing on the percentage of phosphorus found in the crop. The results given in Table V show that the addition of nitrogen alone in nitrate of soda to both the Wooster and Strongsville soils decreases the amounts of phosphorus in the grain below that found in the grain from the unfertilized plots, and when phosphorus and nitrogen are used in combination the percentage of phosphorus is lower than when phosphorus alone is applied.

The crops from Plots 11 and 12 on the Wooster soil, receiving phosphorus, nitrogen and potassium, have a lower phosphorus content than the crop from Plot 6, which receives phosphorus and nitrogen only; while the same treatment on the Strongsville soil increases the phosphorus above that found in the crop fertilized with phosphorus and nitrogen only. On both these soils, however, the additional amount of nitrogen on Plot 12 has decreased the percentage of phosphorus in the crop as compared with Plot 11.

TABLE V—PHOSPHORUS CONTENT OF WHEAT CROP GROWN ON WOOSTER AND STRONGSVILLE SOILS IN 1908—PERCENT

Plot	Treatment	Wooster			Strongsville		
		Grain	Straw	Entire plant	Grain	Straw	Entire plant
	Unfertilized	.3337	.0506	.161	.3270	.0501	.158
5	Nitrogen	.3245	.0589	.155	.2837	.0416	.128
2	Phosphorus	.3642	.0343	.172	.4122	.0447	.186
6	Phosphorus, Nitrogen	.3422	.0331	.157	.3643	.0429	.176
11	Phosphorus, Potassium, Nitrogen	.3380	.0417	.157	.4194	.0458	.197
12	Phosphorus, Potassium, Nitrogen	.3337	.0372	.148	.4153	.0423	.189

Further illustrations of the relation between the composition of the crop and the soil are furnished by the analysis of the crops grown on Strongsville soils receiving applications of insoluble phosphorus. Untreated rock phosphate, or floats, containing 12 percent phosphorus, has been applied to one-half of a series of plots devoted to 5-year rotation fertilizer experiments on the Strongsville soil, and lime to the other half. The average results for four otherwise unfertilized plots, given in Table VI, show a marked increase in the amount of phosphorus in the crop from the soil receiving phosphorus:

TABLE VI—EFFECT OF TREATMENT OF SOIL ON PERCENTAGE OF PHOSPHORUS IN THE CROP

Treatment	Phosphorus in grain	Phosphorus in straw	Phosphorus in entire plant	Phosphorus in soil soluble in N/5 nitric acid
Rock phosphate	.4645	.0511	.203	.0186
Lime	.2947	.0354	.114	.0006

The complete data of the Strongsville crops for the years 1908 and 1909 are given farther on.

Table VII gives the percentages of phosphorus found in the wheat crop grown on seven plots of the manure experiment on the Wooster soil, the amounts of phosphorus soluble in N/5 nitric acid being also shown. Plots 2 and 3 receive 8 tons of manure reenforced with floats, and Plots 5 and 6 the same amount of manure reenforced with acid phosphate. The carriers of phosphorus are added to the manure at the rate of 40 lbs. per ton, or 320 lbs. per acre; the rock phosphate carries 39 lbs. of insoluble phosphorus, and the acid phosphate 20 lbs. of available phosphorus per acre.

TABLE VII-PHOSPHORUS CONTENT OF WHEAT CROP GROWN ON SOIL TREATED WITH YARD AND STALL MANURE REENFORCED WITH FLOATS AND ACID PHOSPHATE PERCENT

Plot	Treatment	Phosphorus in grain	Phosphorus in straw	Phosphorus in entire plant	Phosphorus in soil soluble in N/5 nitric acid
1	None	.3679	.0531	.1431	.0003
2	Yard manure and floats	.3887	.0657	.1624	.0010
3	Stall manure and floats	.4345	.0757	.1803	.0024
4	None	.3209	.0482	.1302	.0003
5	Yard manure and acid phosphate	.4083	.0548	.1621	.0005
6	Stall manure and acid phosphate	.4205	.0636	.1731	.0005
7	None	.3374	.0476	.1414	.0003

Although the above results are not strictly in accordance with the total amounts of phosphorus applied, taken as a whole there are considerable variations in the phosphorus content of the crop and soil from the fertilized and unfertilized plots.

EFFECT OF LIME ON THE PHOSPHORUS ASSIMILATED BY THE WHEAT CROP

The addition of lime to soils having an insufficient supply exerts a beneficial effect in various ways. One of the functions attributed to lime is its action on the insoluble phosphates which are present in the soil, chiefly in the forms of calcium, magnesium, iron and aluminum phosphates. The increased availability of these phosphates may be due to a chemical reaction between the lime and the iron and aluminum phosphates, as well as to the more favorable biological conditions produced by increasing the lime supply.

When phosphorus in the soluble form is applied to the soil it readily combines with the bases present and forms insoluble phosphates, and it is reasonable to suppose that soils supplied with an adequate amount of lime will have a greater proportion of their phosphorus in the form of the more available calcium phosphates than soils deficient in lime.

A comparison of the composition of the wheat crop grown on the same soil, limed at different intervals, shows that the crop from the more recently limed soil contains the larger percentage of phosphorus. Associated with this increased amount of phosphorus are the same variations in the nitrogen and potassium content which are produced by the addition of available phosphorus.

The east and west halves of sections E and B, in the 5-year rotations at Wooster, have received applications of lime as follows: The west half of Section E was limed in 1900, and the east half in 1905; the west half of Section B in 1901, and the east half 5 years later, in 1906, the lime in all cases being applied to the corn crop. The yields of grain and straw obtained from both ends of these sections for the wheat crops of 1907 and 1908 are irregular. The average yields from the fertilized and unfertilized plots are as follows:

TABLE VIII—AVERAGE YIELD OF WHEAT IN POUNDS PER ACRE

	1907				1908			
	Grain		Straw		Grain		Straw	
Date of liming	1905	1900	1905	1900	1906	1901	1906	1901
End of plot	East	West	East	West	East	West	East	West
Average of all plots	1,314	1,276	2,545	2,552	1,617	1,729	2,506	2,818
Average of unfertilized plots	877	784	1,586	1,531	1,065	1,240	1,668	2,103

The average percentages of phosphorus, nitrogen and potassium in the crops are set forth in Table IX, page 12.

The phosphorus content of the grain and straw is uniformly greater on the east half of the plots, and the nitrogen percentages are greater on the west half. Although the percentage of potassium in the entire plant is greatest on the west half, the results show an increased amount in the grain from the more recently limed soil. Table X, page 13 shows that the addition of available phosphorus to the soil increases the phosphorus and decreases the nitrogen and potassium in the wheat plant, and causes a greater transference of potassium from the straw to the grain.

A survey of these results in connection with those set forth in Table IX gives evidence of the effect of lime on the insoluble soil phosphates.

PHOSPHORUS CONTENT

Approximately 80 percent of the phosphorus which is present in the wheat plant at maturity is contained in the grain as organic phosphorus. The ratio of phosphorus in the grain to that in the straw is not uniform for the crops grown under different conditions of fertilization. With an increased supply of available phosphorus there is a tendency toward a greater transference of phosphorus from the straw to the grain.

The addition of nitrogen to the soil not only decreases the total phosphorus content of the plant, but also causes a greater proportion of the phosphorus to be retained in the straw; this is probably due to the effect of nitrogen in prolonging the period of growth.

TABLE IX—EFFECT OF LIME ON PHOSPHORUS, POTASSIUM AND NITROGEN CONTENT OF THE WHEAT PLANT

	Phosphorus in wheat grain				Phosphorus in wheat straw				Phosphorus in entire plant			
	1907		1908		1907		1908		1907		1908	
Date of liming	1905	1900	1906	1901	1905	1900	1906	1901	1905	1900	1906	1901
End of plot	East	West	East	West	East	West	East	West	East	West	East	West
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Average of all plots	.3333	.3137	.3508	.3260	.0499	.0492	.0437	.0383	.1471	.1372	.1632	.1471
Check plots	.3124	.2982	.3337	.3131	.0488	.0586	.0506	.0431	.1434	.1390	.1614	.1434
Plots receiving phosphorus	.3489	.3230	.3664	.3405	.0495	.0432	.0382	.0345	.1492	.1353	.1680	.1522
	Nitrogen in wheat grain				Nitrogen in wheat straw				Nitrogen in entire plant			
Average of all plots	1.822	1.925	1.683	1.766	.4071	.4190	.3814	.3852	.8924	0.9223	.8904	.9071
Check plots	1.843	1.997	1.724	1.825	.4543	.5224	.4441	.4441	.9491	1.0251	.9442	.9580
Plots receiving nitrogen	1.810	1.880	1.677	1.741	.3940	.3681	.3552	.3590	.8663	0.8690	.8691	.8853
	Potassium in wheat grain				Potassium in wheat straw				Potassium in entire plant			
Average of all plots	.3684	.3517	.3630	.3372	.7285	.7818	.8887	0.9232	.6041	.6381	.678	.6890
Check plots	.3814	.3661	.3605	.3292	.7120	.7982	.7843	0.8004	.5930	.6552	.6160	.6233
Plots receiving potassium	.3599	.3445	.3671	.3458	.7645	.7773	.9968	1.0342	.6223	.6324	.7422	.7581

TABLE X—EFFECT OF FERTILIZING ELEMENTS ON THE COMPOSITION OF THE WHEAT PLANT

Treatment	Composition of plant								
	Grain			Straw			Entire plant		
Wooster soil	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Average unfertilized plots........	1.724	.3337	.3605	.4442	.0506	.7843	0.9442	.1612	.6161
2, Phosphorus....	1.505	.3642	.3746	.2671	.0343	.6953	0.7880	.1721	.5604
5, Nitrogen.......................	1.885	.3245	.3512	.5870	.0589	.6888	1.0613	.1550	.5652
3, Potassium................	1.710	.3337	.3464	.4335	.0480	.9281	0.9304	.1581	.6963
Strongsville soil									
Average unfertilized plots........	2.090	.3270	.4089	.4214	.0501	1.0264	1.0762	.1581	.7822
2, Phosphorus.....................	1.840	.4122	.4735	.3103	.0447	0.9507	0.9011	.1864	.7651
5, Nitrogen...............	2.160	.2837	.3772	.4721	.0416	1.1505	1.0790	.1281	.8704
3, Potassium......	2.160	.3014	.3857	.4632	.0449	1.1387	1.1624	.1504	.8260

Table XI shows the percentages of phosphorus found in the grain and straw and in the entire plant, and the pounds removed per acre by the wheat crop grown on the 30 plots of the 5-year rotation fertility work at Wooster. An inspection of these results shows that in general, the percentage of phosphorus found in the wheat grain has varied with the total quantity of phosphorus given in the fertilizer, excepting that the presence of nitrate of soda in the fertilizer seems to have had a restraining influence on the deposit of phosphorus.

It seems that the addition of potassium alone (Plot 3) has increased the deposit of phosphorus in the grain, whereas the nitrate of soda used alone (Plot 5) or with potassium (Plot 9) has reduced the phosphorus in the grain below that from the unfertilized land. Plot 15, fertilized only on wheat, and Plot 14, fertilized on corn and wheat only, stand between the partially fertilized plots 5 and 9, on the one hand, which receive no phosphorus in the fertilizer, and Plots 6, 11, 26, 27 and 29, on the other hand, which receive the complete application on the three cereal crops, corn, oats and wheat, the nitrogen for all being carried in nitrate of soda; there being a gradual transition in the phosphorus content of the grain in the three groups. Plot 12, receiving the maximum application of nitrate, shows a slight reduction in crop phosphorus, as compared with the group receiving less nitrate associated with the same quantity of phosphorus.

In the next group, receiving 30 pounds of phosphorus and 38 pounds of nitrogen, Plot 17, receiving its nitrogen in nitrate of soda, shows practically the same percentage of phosphorus in the crop as the group receiving 20 pounds of phosphorus and 76 pounds of nitrogen, but all the plots to which the nitrogen is applied in organic form show increased percentages of phosphorus in the crop, excepting Plot 20, which receives the small dressing of 8 tons of yard manure, 4 tons each on corn and wheat. If we compare the yield of this plot with that of Plot 14, which receives chemical fertilizers on corn and wheat only, it would seem that the constituents of the yard manure have been less effective, pound for pound, than those of the chemicals, and this may be the explanation of this apparent discrepancy. When the manure has been applied in the larger quantity, on Plot 18, we find the phosphorus rising in the grain.

Apparently, sulphate of ammonia has also had a slightly restraining effect on the deposit of phosphorus, though less marked than in the case of nitrate of soda.

TABLE XI—PHOSPHORUS CONTENT OF WHEAT CROPS GROWN IN 5-YEAR ROTATION AT WOOSTER, AVERAGE RESULTS FOR 1907 AND 1908

Plot No.	Fertilizing elements per acre for one 5-year rotation: Phosphorus	Potassium	Nitrogen	Nitrogen carrier	Average yield per acre: Grain	Straw	Total produce	Phosphorus in crop: In grain	In straw	In entire plant	Phosphorus removed per acre
	Lbs.	Lbs.	Lbs		Bu.	Lbs.	Lbs.	Percent	Percent	Percent	Lbs.
0	0	...	..	Unfertilized	16.53	1,722	2,714	.3143	.0508	.1470	3.99
3	0	108	..	Nonitrogen	19.55	2,131	3,304	.3300	.0478	.1481	5.28
5	0	0	76	Nitrate of soda	20.60	2,373	3,609	.2985	.0533	.1370	4.94
9	0	108	76	" " "	21.06	2,396	3,660	.2955	.0504	.1342	4.92
15	10	41	25	" " "	30.87	3,212	5,064	.3016	.0345	.1321	6.69
14	15	75	51	" " "	34.18	3,623	5,674	.3192	.0348	.1372	7.77
6	20	0	76	" " "	34.43	3,618	5,684	.3326	.0420	.1473	8.36
11	20	108	76	" " "	35.62	3,877	6,014	.3323	.0402	.1434	8.63
26	20	108	76	" " "	29.39	2,901	4,664	.3265	.0431	.1504	7.00
27	20	108	76	" " "	32.54	3,472	5,424	.3362	.0388	.1451	7.90
29	20	108	76	" " "	30.33	3,179	4,999	.3419	.0405	.1506	7.50
12	20	108	114	" " "	34.70	4,047	6,129	.3241	.0403	.1410	8.88
17	30	108	38	" " "	30.37	3,212	5,034	.3388	.0410	.1481	7.49
21	30	108	38	Linseed oilmeal	26.45	2,782	4,369	.3658	.0388	.1560	6.84
23	30	108	38	Dried blood	25.87	2,542	4,094	.3650	.0440	.1654	6.75
24	30	108	38	Sulphate of ammonia..	28.47	3,061	4,769	.3562	.0416	.1532	7.32
30	30	108	38	Tankage	29.68	3,083	4,864	.3794	.0498	.1714	8.29
20	24	56	72	Yard manure	24.98	2,751	4,250	.3350	.0355	.1404	5.98
18	48	112	144	" "	31.68	3,263	5,164	.3678	.0484	.1663	8.58
2	20	...	..	No nitrogen	27.18	2,818	4,449	.3692	.0463	.1642	7.82
8	20	108	..	" "	26.24	2,649	4,223	.3687	.0437	.1641	6.92

Finally, the effect of an excess of available phosphorus in the soil over the nitrogen supply is again shown in the high percentage of phosphorus in the crops grown on Plots 2 and 8. It is interesting to compare these plots with numbers 5 and 9, both with reference to total yields and to composition of the grain.

The larger percentage of phosphorus in the grain from Plot 29 is in harmony with the effect of lime previously noted, the phosphorus carrier for this plot being basic slag. On Plot 26 the phosphorus carrier is raw bonemeal and on Plot 27 it is dissolved boneblack. On all the others, except the manured plots, it is acid phosphate.

The average results shown in Table XI are summarized in Table XII.

TABLE XII—AVERAGE PERCENTAGE OF PHOSPHORUS IN THE WHEAT GRAIN AT WOOSTER

Treatment	Phosphorus in grain
	Percent
Unfertilized	.3143
Nitrogen or potassium without phosphorus	.3080
Phosphorus, without nitrogen	.3690
Phosphorus, with nitrate of soda	.3332
Phosphorus, with organic nitrogen	.3615

In the Strongsville experiments, as in those at Wooster, the wheat is grown in a 5-year rotation of corn, oats, wheat and clover on five tracts of land, Sections A, B, C, D and E, each crop being grown every year. The wheat crops of 1908 and 1909 were harvested from Sections E and A. In 1901 and 1902 one half of each of these sections was dressed with quicklime, applied at the rate of one ton per acre. In September, 1905, the limed half of Section E received another dressing of lime, applied to one half (one-fourth of the entire tract) at the rate of one ton and to the other half at two tons, per acre, and the unlimed half received an application of finely ground phosphate rock, or floats, applied to one quarter at the rate of one-half ton and to the other quarter at one ton per acre.

In the spring of 1907 Section E was dressed with lime and floats applying both materials at the rate of one ton and two tons per acre.

The composition of the wheat harvested in this experiment in 1908 and 1909 has been determined, with the results shown in Table XIII.

TABLE XIII—PHOSPHORUS CONTENT OF WHEAT CROP GROWN ON STRONGSVILLE SOIL. AVERAGE RESULTS FOR HALVES OF PLOTS RECEIVING LIME AND FLOATS 1908-1909

Plot No.	Fertilizing elements per acre for one 5-year rotation			Phosphorus in					
				Grain		Straw		Entire plant	
	Phosphorus	Potassium	Nitrogen	Floats	Lime	Floats	Lime	Floats	Lime
	Lbs.	Lbs.	Lbs.	Percent	Percent	Percent	Percent	Percent	Percent
Average unfertilized	..	...	...	.4352	.3108	.0467	.0428	.1877	.1368
2	20	..	...	.4569	.4119	.0489	.0424	.1984	.1718
3	..	108	...	.4502	.3113	.0426	.0391	.1822	.1362
5	..	...	76	.4175	.2806	.0355	.0353	.1691	.1172
6	20	...	76	.4621	.3744	.0389	.0359	.2003	.1678
8	20	108	...	.4527	.3962	.0404	.0458	.1997	.1811
9	..	108	76	.4285	.3160	.0387	.0346	.1595	.1370
11	20	108	76	.4504	.4395	.0460	.0459	.1969	.1862
12	20	108	114	.4520	.4301	.0466	.0463	.1975	.1899

This table shows that the percentage of phosphorus in the wheat is decidedly higher on the land treated with floats than on that dressed with lime, and that it is higher in the crop of 1909, following the larger application of floats, than in that of 1908, whereas the wheat grown on the limed land shows less phosphorus in 1909 than in 1908. In 1908 the further addition of phosphorus in the fertilizer has caused an increase in the phosphorus percentage of the grain, but in 1909 the large dressing of floats has apparently furnished all the phosphorus the plant could utilize.

The average results shown in Table XIII are summarized in Table XIV:

TABLE XIV—AVERAGE PERCENTAGE OF PHOSPHORUS IN THE WHEAT GRAIN AT STRONGSVILLE

Plot treatment	Year and cross dressing			
	1908		1909	
	Floats	Lime	Floats	Lime
	Percent	Perceut	Percent	Percent
Unfertilized	.4059	.3270	.4646	.2947
Nitrogen, in nitrate of soda	.4168	.2837	.4182	.2775
Phosphorus, without nitrogen or potassium	.4449	.4122	.4689	.4116
Phosphorus, with nitrate of soda only	.4572	.3643	.4671	.3845
Phosphorus, potassium and nitrogen	.4287	.4173	.4736	.4522

It will be observed that the reenforcement of phosphorus with potassium, and with nitrogen in nitrate of soda, has apparently increased the deposit of phosphorus in the grain at Strongsville, an effect the

opposite of that observed at Wooster. On referring to Table IV we see that the effect of both nitrogen and potassium on the total yield has been much smaller at Strongsville than at Wooster, an effect in harmony with the analysis of the two soils. The effect of the carriers of organic nitrogen on the composition of the grain has not yet been studied at Strongsville.

TABLE XV—POTASSIUM CONTENT OF WHEAT CROP GROWN IN 5-YEAR ROTATION AT WOOSTER: AVERAGE RESULTS FOR 1907 and 1908

Plot No.	Treatment for 5-year rotation			Potassium in			Average yield for 1907-1908		Potassium removed by grain and straw
	Phosphorus	Potassium	Nitrogen	Grain	Straw	Entire plant	Grain	Straw	
	Lbs.	Lbs.	Lbs	Percent	Percent	Percent	Bus.	Lbs.	Lbs.
0*	..	...	...	.3591	.7737	.621	16.53	1,722	17.03
2	20	...	...	.3621	.6675	.554	27.18	2,818	24.89
3	..	108	.	.3269	.8739	.678	19.55	2,131	22.46
5	..	...	76	.3367	.7376	.601	20.60	2,373	21.72
6	20	...	76	.3371	.7257	.584	34.43	3,618	33.25
8	20	108	...	.3528	.8873	.684	26.24	2,649	29.38
9	..	108	76	.3438	.9757	.756	21.06	2,396	28.08
11	20	108	76	.3366	.9398	.720	35.62	3,877	43.47
12	20	108	114	.3547	.9481	.734	34.70	4,047	46.28
14	15	75	51	.3489	.8424	.660	34.18	3,623	37.85
15	10	41	25	.3429	.8645	.668	30.87	3,212	33.97
17	30	108	38	.3652	.8539	.673	30.37	3,212	34.18
18	48	112	144	.3681	.8644	.676	31.68	3,263	34.88
20	24	56	72	.3413	.7819	.622	24.98	2,751	26.45
21	30	108	38	.3709	.8782	.690	26.45	2,782	30.48
23	30	108	38	.3681	.8661	.675	25.87	2,542	28.13
24	30	108	38	.3633	.8982	.703	28.47	3,061	33.70
26	20	108	76	.3598	.9245	.704	29.39	2,901	32.92
27	20	108	76	.3468	.8865	.665	32.54	3,472	34.67
29	20	108	76	.3519	.8921	.692	30.33	3,179	34.80
30	30	108	38	.3685	.8702	6.84	29.68	3 083	33.25

*Average of unfertilized plots.

POTASSIUM CONTENT

The potassium percentages found in the wheat grain and straw grown on the differently fertilized plots are given in Tables XV and XVI. Inspection of the results in these tables shows that the addition of potassium alone or in combination with phosphorus and nitrogen has uniformly increased the amount of potassium in the

wheat crop grown on Wooster soil and has generally done so at Strongsville. The percentages found in the crop from the Strongsville soil, as shown in Table XVI, are greater than those found in the Wooster crop and the increase from additions of potassium in the fertilizer are less uniform; this is attributed to the larger supply of potassium in the Strongsville soil.

It will be observed that phosphorus, in the form of raw rock phosphate, has affected the distribution of potassium in the plant in the same manner as applications of the more available phosphorus supplied by acid phosphate; that is, on the floats-treated land a larger percentage of the total potassium is found in the grain than on that not so treated.

TABLE XVI—POTASSIUM CONTENT OF WHEAT CROP GROWN IN 5-YEAR ROTATION AT STRONGSVILLE. AVERAGE RESULTS FOR HALVES OF PLOTS RECEIVING LIME AND FLOATS. 1908 AND 1909

Plot No.	Treatment for 5-year rotation			Potassium in					
				Grain		Straw		Entire plant	
	Phosphorus	Potassium	Nitrogen	Floats	Lime	Floats	Lime	Floats	Lime
	Lbs.	Lbs.	Lbs.	Percent	Percent	Percent	Percent	Percent	Percent
0*	..	...	...	.4259	.3906	0.9858	1.0463	.7817	.8160
2	20	...	...	.4502	.4538	0.9702	0.9751	.7792	.7929
	..	108	...	.4525	.3879	1.1263	1.1841	.8954	.8975
5	..	. .	76	.4413	.3580	1.0137	1.1038	.8141	.8523
6	20	...	76	.4617	.4044	0.8547	0.8931	.6995	.6982
8	20	108	...	.4586	.4296	0.9233	1.0203	.7406	.7908
9	..	108	76	.4376	.3784	1.0058	1.1033	.7061	.8406
11	20	108	76	.4544	.4372	0.9531	1.0798	.7659	.8552
12	20	108	114	.4357	.4517	0.9858	1.0347	.7792	.8157

*Average of unfertilized plots.

NITROGEN CONTENT

The nitrogen content of the wheat crop grown on the differently fertilized plots of the 5-year rotation work on Wooster soil is given in Table XVII. These results show that the percentage of nitrogen in the wheat plant is influenced by the supply of phosphorus and nitrogen at its disposal. The higher nitrogen content of the wheat plant grown on exhausted soil, over that found in the crops from the plots which have produced normal yields, is apparently due to the decreased elaboration of organic matter.*

The addition of nitrogen without phosphorus has increased the percentage of nitrogen in the crop, as well as the total amount removed. In the crop grown under the opposite condition of

*The wheat grown on the unfertilized plots and on those receiving no phosphorus in the fertilizer generally weighs less per bushel than that grown on the plots receiving phosphorus, especially in unfavorable seasons.

TABLE XVII—NITROGEN CONTENT OF WHEAT GROWN IN 5-YEAR ROTATION AT WOOSTER. AVERAGE RESULTS FOR 1907 AND 1908

Plot No.	Fertilizing elements per acre for one 5-year rotation			Nitrogen carrier	Nitrogen content			Average yield per acre, 1907 and 1908		Nitrogen removed per acre	Plot No.
	Phosphorus	Potassium	Nitrogen		Grain	Straw	Entire plant	Grain	Straw		
	Lbs.	Lbs.	Lbs.		Percent	Percent	Percent	Bus.	Lbs.	Lbs.	
..	..	...	...	Unfertilized	1.841	.466	0.968	16.53	1,722	26.25	..
2	20	...	...	No nitrogen	1.660	.301	0.799	27.18	2,818	35.52	2
3	..	108	...	"	1.832	.449	0.940	19.55	2,131	30.85	3
8	20	108	...	"	1.691	.316	0.826	26.24	2,649	35.07	8
15	10	41	25	Nitrate of soda	1.782	.345	0.867	30.87	3,216	43.98	15
14	15	75	51	" "	1.811	.343	0.869	34.18	3,623	49.34	14
5	..	...	76	" "	2.103	.592	1.107	20.60	2,373	39.92	5
9	..	108	76	" "	2.084	.536	1.059	21.06	2,396	38.53	9
6	20	...	76	" "	1.831	.355	0.355	34.43	3,618	50.54	6
11	20	108	76	" "	1.823	.368	0.883	35.62	3,877	53.17	11
26	20	108	76	" "	1.741	.370	0.889	29.39	2,901	41.47	26
27	20	108	76	" "	1.714	.340	0.833	32.54	3,472	45.27	27
29	20	108	76	" "	1.742	.352	0.858	30.33	3,179	42.75	29
12	20	108	114	" "	2.004	.411	0.976	34.40	4,047	61.33	12
17	30	108	38	" "	1.661	.300	0.789	30.37	3,212	40.33	17
21	30	108	38	Linseed oilmeal	1.613	.307	0.774	26.45	2,782	33.91	21
23	30	108	38	Dried blood	1.581	.295	0.779	25.87	2,542	32.00	23
24	30	108	38	Sulphate of ammonia	1.634	.310	0.781	28.47	3,061	37.44	24
30	30	108	38	Tankage	1.651	.312	0.803	29.68	3,083	39.28	30
20	24	56	72	Yard manure	1.692	.330	0.807	24.98	2,751	34.34	20
18	48	112	144	" "	1.751	.351	0.866	31.68	3,263	44.82	18

fertilization, that is, a supply of phosphorus without nitrogen, there has been a decided dècrease in the percent of nitrogen, but a much larger quantity of total nitrogen removed.

Comparing the results for plots 11 and 12, which have produced practically equal yields under the same conditions of fertilization, with the exception of an additional amount of nitrogen on plot 12, it will be observed that the nitrogen content of the crop from plot 12 has been materially increased.

The enhanced accumulation of nitrogen in the entire plant is distributed differently than the increases of phosphorus and potassium; the increased phosphorus is transferred to the grain, and the potassium is retained in the straw, while the nitrogen is distributed in both grain and straw.

Table XVIII summarizes the data obtained from the analyses of the wheat crop grown on Strongsville soil. An inspection of these results shows an increased percentage of nitrogen over that found in the crop from the Wooster soil, and a larger percentage in the wheat grown on the limed land than on that cross-dressed with floats. Table XIX gives the yield per acre and the percentage of nitrogen in the grain for each of the two seasons. This table shows that in 1908 there was but little difference between the yield per acre of the land cross-dressed with floats and that treated with lime, while in 1909 the floats treated land produced generally the larger yield.

TABLE XVIII—NITROGEN CONTENT OF WHEAT GROWN IN 5-YEAR ROTATION AT STRONGSVILLE. AVERAGE FOR 1908 AND 1909

Plot No.	Fertilizing elements per acre for one 5-year rotation			Nitrogen content					
				Cross-dressed with floats			Cross-dressed with lime		
	Phosphorus	Potassium	Nitrogen	Grain	Straw	Entire plant	Grain	Straw	Entire plant
	Lbs.	Lbs.	Lbs.	Percent	Percent	Percent	Percent	Percent	Percent
..	..	...	...	1.812	.305	.852	2.159	.458	1.055
2	20	...	...	1.775	.235	.802	1.942	.338	0.898
3	..	108	...	1.900	.290	.841	2.185	.465	1.085
8	20	108	...	1.740	.258	.831	1.957	.307	0.943
5	..	...	76	1.837	.263	.814	2.290	.485	1.086
9	..	108	76	1.825	.273	.854	2.160	.406	1.033
6	20	...	76	1.770	.237	.823	2.025	.343	1.003
11	20	108	76	1.780	.276	.837	1.967	.351	0.929
12	20	108	114	1.795	.257	.831	1.985	.363	0.970

Our records show that the land on which the wheat was grown in 1908 had received only half the quantity of floats that was used subsequently. In every case however the wheat grown on the limed land has shown a higher percentage of nitrogen than that grown on the land treated with floats.

TABLE XIX—YIELD PER ACRE AND PERCENTAGE OF NITROGEN IN THE GRAIN OF WHEAT GROWN IN 5-YEAR ROTATION AT STRONGSVILLE

Plot No.	Fertilizing elements per acre for one 5-year rotation			Yield of grain per acre				Nitrogen in grain			
				1908		1909		1908		1909	
	Phosphorus	Potassium	Nitrogen	Floats	Lime	Floats	Lime	Floats	Lime	Floats	Lime
	Lbs.	Lbs.	Lbs.	Bus.	Bus.	Bus.	Bus.	Percent	Percent	Percent	Percent
..	..	...	...	12.15	15.84	17.47	9.33	1.800	2.096	1.827	2.225
2	20	...	...	20.09	18.92	15.67	14.00	1.824	1.843	1.730	2.045
3	..	108	...	7.92	14.17	14.67	8.67	1.831	2.161	1.970	2.210
8	20	108	...	25.33	21.59	18.67	21.67	1.742	1.881	1.740	2.035
5	..	...	76	12.09	18.58	20.00	8.67	1.880	2.162	1.795	2.420
9	..	108	76	15.92	16.42	18.00	11.00	1.830	2.023	1.820	2.300
6	20	...	76	28.25	24.59	19.67	23.33	1.814	2.061	1.730	1.990
11	20	108	76	29.59	25.08	20.00	20.33	1.751	1.871	1.810	2.065
12	20	108	114	28.67	23.75	22.67	26.67	1.742	1.803	1.850	2.175
Average of all plots				20.00	19.88	18.54	15.96	1.802	1.989	1.808	2.163

SUMMARY

The percentages of phosphorus, potassium and nitrogen in the wheat crops analyzed exhibit a wide range of variation. In the grain the differences between the maximum and minimum amounts found are practically the same for each of these constituents; the variations in the straw do not show as marked a uniformity.

The composition of the wheat crop grown on the unfertilized plots of two soils, containing different amounts of phosphorus, potassium and nitrogen, is in accordance with the composition of these soils.

The proportion of phosphorus, potassium and nitrogen in the wheat plant is increased by the addition of these elements to the soil.

Although the extent of variation due to seasonal conditions is greater than that produced by changes in the composition of the soil, the variations due to soil treatment are relatively the same for the different seasons.

Phosphorus applied to soil, showing a deficiency of this element as measured by crop yields, increases the amount of phosphorus in the grain. Associated with this increased accumulation of phosphorus there is an increased quantity of potassium and a decreased amount of nitrogen.

The addition of lime to the soil increases the amount of phosphorus assimilated by the wheat plant. With this increase in the phosphorus content there are the same variations in the nitrogen and potassium as are produced by the addition of phosphorus.

The composition of the wheat crop from plots on the same soil treated with five different carriers of phosphorus, namely: acid phosphate, bone meal, dissolved bone black, basic slag, and barnyard manure, shows that the phosphorus content of the wheat plant has been increased to the greatest extent by manure.

The application of untreated rock phosphate to a soil well supplied with nitrogen and potassium, increases the phosphorus content of the wheat plant to a marked extent.

The percentage of nitrogen in the wheat plant varies with the supply at its disposal, and is also influenced to a considerable extent by the supply of phosphorus.

An increase in the potassium supply of the soil is reflected in the potassium content of the straw.

A comparison of the composition of the wheat plant grown on the same soil, under different conditions of fertilization, gives a better indication of the available supply of nitrogen, phosphorus and potassium in the soil than can be obtained from the analysis of the soil itself.*

*For data upon the relation of the soil and its treatment to the composition of Blue-grass the reader is referred to Bulletin 222 of this Station.

ADDENDA

Detailed results are given in the following tables:

Table XX—Nitrogen, phosphorus and potassium content of wheat grain and straw from east and west ends of the 5-year rotation fertilizer plots at Wooster, Section E. 1907.

Table XXI—Nitrogen, phosphorus and potassium content of wheat grain and straw from east and west ends of the 5-year rotation fertilizer plots at Wooster, Section B. 1908.

Table XXII—Nitrogen and phosphorus content of wheat crop, 5-year rotation at Wooster, 1904.

Table XXIII—Nitrogen, phosphorus and potassium content of wheat crop, continuous culture at Wooster, 1908.

Table XXIV—Nitrogen content of wheat grain and straw, 5-year rotation at Wooster, 1902, 1904, 1906, 1907, and 1908.

Table XXV—Nitrogen, phosphorus and potassium content of wheat crop, 5-year rotation, at Strongsville 1908 and 1909. Plots treated with lime and floats.

Table XXVI—Pounds of nitrogen, phosphorus and potassium removed per acre by wheat crop at Strongsville, 5-year rotation, from halves of plots receiving lime and floats, 1908 and 1909.

Table XXVII—Pounds of nitrogen removed per acre by wheat grain and straw, 5-year rotation at Wooster, 1902, 1904, 1905, 1906, 1907, and 1908.

Table XXVIII—Pounds of potassium removed per acre by wheat grain and straw, 5-year rotation plots at Wooster, 1907 and 1908.

Table XXIX—Pounds of phosphorus removed per acre by wheat grain and straw, 5-year rotation at Wooster, 1904, 1907, and 1908.

Table XXX—Ratio of phosphorus to nitrogen. Parts of phosphorus to 100 parts of nitrogen, 5-year rotation at Wooster.

Table XXXI—Percentage increase yield and percentage increase phosphorus removed by wheat crop on fertilized plots, 5-year rotation at Wooster.

Table XXII—Percentage increase yield and percentage increase potassium removed by wheat crop on fertilized plots, 5-year rotation at Wooster.

Table XXXIII—Percentage increase yield and percentage increase nitrogen removed by wheat crop on fertilized plots, 5-year rotation at Wooster.

TABLE XX—NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF WHEAT GRAIN AND STRAW FROM EAST AND WEST ENDS OF THE 5-YEAR ROTATION FERTILIZER PLOTS AT WOOSTER, SEC. E., 1907. WEST END LIMED 1900. EAST END LIMED 1905.

Plot No.	Fertilizing elements per acre for one 5-year rotation			Grain						Straw						Plot No.
				Nitrogen		Phosphorus		Potassium		Nitrogen		Phosphorus		Potassium		
	Phosphorus	Potassium	Nitrogen	West end	East end	West end	East end	West end	East end	West end	East end	West end	East end	West end	East end	
	Lbs.	Lbs.	Lbs.	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	
1	..	...	...	2.081	2.023	.3012	.3380	.3224	.4161	.5202	.5651	.0628	.0692	1.087	.773	1
2	20	...	...	1.840	1.791	.3521	.4151	.3380	.3880	.2904	.3504	.0426	.0700	0.746	.491	2
3	..	108	...	1.972	1.842	.3443	.3390	.3412	.3831	.5003	.3951	.0481	.0489	0.744	.763	3
4	..	...	...	2.083	1.901	.3110	.3224	.3371	.3790	.4851	.4602	.0588	.0509	0.884	.686	4
5	..	...	76	2.331	2.080	.2912	.3103	.3342	.3841	.6002	.6050	.0526	.0572	0.669	.711	5
6	20	...	76	1.970	1.891	.3260	.3621	.3214	.3513	.3400	.3404	.0451	.0493	0.858	.655	6
7	..	...	...	2.012	1.903	.3081	.3190	.3351	.3832	.4602	.4802	.0567	.0522	0.681	.662	7
8	20	108	...	1.781	1.782	.3334	.3951	.3142	.3814	.3081	.3401	.0414	.0688	0.715	.750	8
9	..	108	76	2.283	2.043	.3014	.2920	.3431	.3551	.5504	.5652	.0564	.0576	0.864	.847	9
10	..	...	...	2.112	1.841	.2981	.3181	.3504	.3804	.5203	.4101	.0601	.0443	0.701	.782	10
11	20	108	76	1.902	1.830	.3152	.3422	.3260	.3621	.3204	.3404	.0377	.0423	0.826	.789	11
12	20	108	114	2.113	2.063	.3160	.3181	.3021	.3361	.3902	.4202	.0476	.0423	0.801	.835	12
13	..	...	...	2.001	1.882	.2953	.2923	.3761	.3632	.4560	.4851	.0564	.0497	0.698	.710	13
14	15	75	51	1.902	1.881	.3034	.3181	.3423	.3470	.3401	.4103	.0456	.0335	0.716	.668	14
15	10	41	25	1.861	1.840	.2781	.2952	.3241	.3434	.3500	.3650	.0385	.0356	0.739	.765	15
16	..	...	...	2.003	1.841	.2862	.2912	.3843	.3804	.6004	.4301	.0663	.....	0.791	.705	16
17	30	108	38	1.791	1.783	.3381	.2951	.3551	.3591	.3102	.3403	.0406	.0576	0.755	.700	17
18	48	112	144	1.890	1.862	.3362	.3852	.3514	.3790	.4063	.3604	.0489	.0584	0.807	.712	18
19	..	...	...	2.031	1.801	.2880	.3504	.3860	.3672	.5901	.4102	.0547	.0410	0.737	.686	19
20	24	56	72	1.842	1.693	.3004	.3730	.3741	.3362	.3500	.3204	.0402	.0348	0.729	.695	20
21	30	108	38	1.790	1.612	.3451	.3641	.3842	.3514	.3304	.3203	.0406	.0414	0.800	.753	21
22	..	...	...	1.923	1.701	.2953	.2842	.3923	.3718	.5402	.4001	.0559	.0386	0.816	.715	22
23	30	108	38	1.651	1.591	.3480	.3551	.3790	.3731	.2901	.3404	.0461	.0543	0.760	.758	23
24	30	108	38	1.690	1.672	.3404	.3590	.3872	.3622	.3168	.3601	.0418	.0534	0.800	.798	24
25	..	...	...	1.892	1.801	.3041	.2814	.4080	.3590	.5302	.4402	.0613	.0451	0.763	.702	25
26	20	108	76	1.741	1.762	.3152	.3171	.3542	.3732	.3504	.4004	.0431	.0447	0.751	.744	26
27	20	108	76	1.761	1.741	.2970	.3390	.3261	.3491	.3508	.3650	.0387	.0501	0.843	.773	27
28	..	...	...	1.863	1.752	.2924	.3262	.3680	.4164	.5304	.4604	.0530	.....	0.820	.697	28
29	20	108	76	1.751	1.791	.3214	.3214	.3514	.3343	.3502	.3651	.0387	.0460	0.749	.768	29
30	30	108	38	1.730	1.723	.3160	.3690	.3360	.3840	.3501	.3803	.0580	.0601	0.787	.750	30

TABLE XXI—NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF WHEAT GRAIN AND STRAW FROM EAST AND WEST ENDS OF THE 5-YEAR ROTATION FERTILIZER PLOTS AT WOOSTER, SEC. B., 1908. WEST END LIMED 1901. EAST END LIMED 1906.

Plot No.	Fertilizing elements per acre for one 5-year rotation			Grain						Straw						Plot No.
				Nitrogen		Phosphorus		Potassium		Nitrogen		Phosphorus		Potassium		
	Phosphorus	Potassium	Nitrogen	West end	East end	West end	East end	West end	East end	West end	East end	West end	East end	West end	East end	
	Lbs.	Lbs.	Lbs.	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	
1	..	...	...	1.903	1.810	.3112	.3370	.3421	.3661	.4902	.5301	.0474	.0564	0.7841	0.8461	1
2	20	...	...	1.551	1.505	.3441	.3641	.3471	.3740	.3001	.2673	.0384	.0343	0.7370	0.6952	2
3	..	108	...	1.810	1.710	.3022	.3332	.2790	.3460	.4670	.4351	.0466	.0480	1.0604	0.9283	3
4	..	...	...	1.842	1.680	.3190	.3470	.2814	.3602	.5021	.4302	.0478	.0605	0.8212	0.6480	4
5	..	...	76	2.123	1.885	.2680	.3243	.2761	.3513	.5803	.5870	.0443	.0589	0.8813	0.6881	5
6	20	...	76	1.761	1.700	.2991	.3421	.3373	.3391	.4302	.3121	.0406	.0331	0.7570	0.6304	6
7	..	...	...	1.802	1.715	.3163	.3423	.2562	.3412	.3651	.3520	.0341	.0394	0.7871	0.8151	7
8	20	108	...	1.681	1.530	.3582	.3881	.3471	.3691	.3550	.2703	.0312	.0335	1.1242	0.9580	8
9	..	108	76	2.050	1.955	.2870	.3012	.3383	.3372	.5152	.5150	.0398	.0478	1.1071	1.0624	9
10	..	...	...	1.963	1.880	.3231	.3140	.3591	.3480	.4321	.4452	.0398	.0400	0.7653	0.8012	10
11	20	108	76	1.771	1.815	.3332	.3381	.2932	.3653	.3953	.4201	.0392	.0417	1.0981	1.0441	11
12	20	108	114	2.043	1.830	.3270	.3334	.4141	.3652	.4254	.4123	.0343	.0372	1.0490	1.1070	12
13	..	...	...	1.832	1.755	.3281	.3201	.3780	.3671	.4500	.4370	.0367	.0474	0.8702	0.7802	13
14	15	75	51	1.831	1.640	.3234	.3321	.3553	.3504	.3352	.2904	.0292	.0308	0.9754	1.0081	14
15	10	41	25	1.740	1.680	.3023	.3293	.3352	.3681	.3571	.3121	.0320	.0320	1.0293	0.9242	15
16	..	...	...	1.822	1.680	.3001	.3370	.3324	.3814	.4503	.4404	.0449	.0619	0.9150	0.8681	16
17	30	108	38	1.621	1.480	.3361	.3851	.3780	.3670	.2850	.2651	.0304	.0357	1.0102	0.9491	17
18	48	112	144	1.683	1.590	.3532	.3944	.3804	.3614	.3221	.3250	.0355	.0509	0.9871	0.9502	18
19	..	...	...	1.861	1.615	.2941	.3510	.3311	.3691	.4323	.4302	.0372	.0572	0.7614	0.7552	19
20	24	56	72	1.662	1.575	.2946	.3712	.2970	.3583	.2852	.3651	.0273	.0400	0.8021	0.9004	20
21	30	108	38	1.533	1.620	.3580	.3943	.3662	.3814	.2871	.2920	.0343	.0390	1.0303	0.9283	21
22	..	...	...	1.812	1.715	.2881	.3301	.3013	.3621	.4453	.4702	.0437	.0544	0.7452	0.7054	22
23	30	108	38	1.601	1.510	.3643	.3914	.3271	.3922	.2672	.2851	.0322	.0435	1.0461	0.8891	23
24	30	108	38	1.642	1.540	.3521	.3720	.3224	.3801	.2771	.2952	.0323	.0388	1.0334	0.9604	24
25	..	...	...	1.741	1.725	.3170	.3212	.3480	.3470	.4424	.5420	.0498	.0607	0.8431	0.7651	25
26	20	108	76	1.691	1.785	.3391	.3321	.3671	.3431	.2751	.4551	.0376	.0470	1.0780	1.1230	26
27	20	108	76	1.662	1.700	.3450	.3612	.3562	.....	.3252	.2224	.0327	.0335	0.9132	1.0152	27
28	..	...	...	1.693	1.665	.3312	.3848	.3604	.3581	.4350	.3720	.0503	.0388	0.7081	0.8541	28
29	20	108	76	1.751	1.690	.3390	.3801	.3501	.3712	.4103	.2871	.0435	.0339	1.0142	1.0360	29
30	30	108	38	1.561	1.620	.4151	.4100	.3532	.3991	.2351	.2852	.0367	.0445	0.9570	[illegible]	30

TABLE XXII—NITROGEN AND PHOSPHORUS CONTENT OF WHEAT CROP, 5-YEAR ROTATION AT WOOSTER 1904

lot o.	Fertilizing elements per acre for one 5-year rotation			Nitrogen in		Phosphorus in	
	Phosphorus	Potassium	Nitrogen	Grain	Straw	Grain	Straw
	Lbs.	Lbs.	Lbs.	Percent	Percent	Percent	Percent
0*	..	...	...	2.065	0.947	.3663	.012
2	20	...	...	2.146	0.640	.3960	.0724
3	..	108	...	2.181	0.965	.3366	.0995
5	..	...	76	2.146	1.056	.3187	.0899
6	20	...	76	2.117	0.494	.4034	.0799
8	20	108	...	1.845	.. ...	.4213	.0921
9	..	108	76	2.115	0.814	.3423	.0943
11	20	108	76	1.950	0.466	.3886	.0961
12	20	108	114	2.120	0.539	.3737	.0860
14	15	75	51	1.930	0.466	.3916	.0519
15	10	41	25	1.990	0.480	.3750	.0676
17	30	108	38	.....	0.376	......	.0755
18	48	112	144	2.035	0.501	.4357	.1030
20	24	56	72	2.050	0.645	.4108	.1013
21	30	108	38	1.830	0.440	.4117	.0655
23	30	108	38	1.794	0.435	.4357	.0833
24	30	108	38	1.874	0.440	.4095	.0890
26	20	108	76	1.979	0.640	.4265	.0890
27	20	108	76	. ...	0.539	......	.0868
29	20	108	76	2.010	0.570	.4012	.0816
30	30	108	38	1.866	0.539	.4073	.1920

*Average of unfertilized plots

TABLE XXIII—NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF WHEAT CROP. CONTINUOUS CULTURE AT WOOSTER, 1908

Plot No.	Fertilizing elements applied per acre			Nitrogen in			Phosphorus in			Potassium in			Plot No.
	Acid phosphate	Muriate potash	Nitrate of soda	Grain	Straw	Entire plant	Grain	Straw	Entire plant	Grain	Straw	Entire plant	
	Lbs.	Lbs.	Lbs.	percent	Percent	Percent	ercent	Percent	Percent	Percent	Percent	Percent	
0	...	...	..	1.896	.5740	0.9691	.3053	.0552	.1335	.3661	0.7747	.6501	0
2	160	100	160	1.775	.4304	0.8720	.4034	.0499	.1659	.3730	0.7735	.6403	2
3	45	30	160	1.925	.4103	0.9192	.3166	.0418	.1340	.3521	0.7598	.6210	3
5	Yard manure 2½ tons			1.710	.4102	0.8714	.3655	.0518	.1628	.3609	0.7847	.6331	5
6	Yard manure 5 tons			1.660	.3821	0.8271	.3839	.0570	.1707	.3899	0.9096	.7280	6
8	160	100	320	1.970	.5570	1.0460	.4144	.0594	.1820	.3923	1.0627	.8291	8
9	90	60	320	2.065	.6122	1.1232	.3154	.0539	.1458	.3601	0.8219	.6583	9

TABLE XXIV—NITROGEN CONTENT OF WHEAT GRAIN AND STRAW, 5-YEAR ROTATION AT WOOSTER—PERCENT

Year	1902		1904		1905	1906	1907		1908		Average		Plot No.
Plot No.	Grain	Straw	Grain	Straw	Grain	Grain	Grain	Straw	Grain	Straw	Grain	Straw	
0*	2.261	.818	2.086	0.947	2.344	2 100	1.918	.488	1.771	.444	2.080	.674	0*
2	1.974	.452	2.146	0.640	1.880	1.820	1.815	.320	1.527	.283	1.860	.423	2
3	2 329	.681	2.181	0.985	2.440	2.240	1.905	.447	1.760	.451	2 159	.641	3
5	2.532	.944	2.146	1.056	2.600	2.400	2.205	.602	2.002	.583	2.314	.796	5
6	2.088	.562	2.117	0.494	2.150	1.930	1.930	.340	1.732	.371	1.991	.441	6
8	1.701	.393	1.845	.....	1.900	1.650	1.780	.320	1.605	.312	1 746	.341	8
9	2.516	.875	2.116	0.814	2.580	2.320	2.165	.557	2.002	.515	2.283	.690	9
11	1.963	.434	1.950	0.466	2.050	1.900	1.865	.330	1.792	.407	1 920	.409	11
12	2.017	.528	2.120	0.539	2.310	1.920	2.085	.405	1.935	.418	2.064	.472	12
14	1.949	.470	1.930	0.466	2.210	1.800	1.890	.375	1.735	.312	1.919	.405	14
15	2 178	.456	1.990	0.480	2.100	1.900	1.850	.357	1.712	.334	1.955	.406	15
17	1.755	.391	.....	0.376	1.900	1.790	1.785	.325	1.550	.275	1.756	.341	17
18	2.006	.485	2.035	0.501	2.000	1.830	1.875	.380	1.635	.323	1.896	.422	18
20	1.948	.572	2.050	0.645	2.250	1.940	1.765	.335	1.620	.325	1.928	.469	20
21	1.618	.356	1.830	0.440	1.980	1.710	1.700	.325	1.525	.289	1.727	.352	21
23	1 641	.369	1.794	0.435	.....	1.740	1.620	.315	1.555	.276	1.670	.348	23
24	1 637	.369	1.674	0.440	1.900	1.930	1.680	.335	1.592	.286	1.768	.357	24
26	2 027	.420	1.979	0 640	2.150	1.930	1.750	.375	1.737	.365	1.928	.450	26
27	1 913	.420	.....	0.539	2.110	1.900	1.750	.357	1.682	.323	1.871	.409	27
29	2.106	.506	2.010	0.570	2.260	2.000	1.770	.357	1.720	.348	1.977	.445	29
30	1.768	.441	1.868	0.539	1.970	1.700	1.725	.365	1.590	.260	1.769	.401	30

*Average of unfertilized plots.

TABLE XXV—NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF WHEAT CROP, 5-YEAR ROTATION AT STRONGSVILLE 1908 AND 1909. PLOTS TREATED WITH LIME AND FLOATS.—PERCENT

Treatment	Grain 1908						Straw 1908						Treatment
	Floats	Lime	Floats	Lime	Floats	Lime	Floats	Lime	Floats	Lime	Floats	Lime	
	Nitrogen		Phosphorus		Potassium		Nitrogen		Phosphorus		Potassium		
Plot No.													Plot No.
1	1.823	2.261	.3997	.3290	.4408	.4296	.3314	.5304	.0597	.0470	0.9619	0.9447	1
2	1.824	1.843	.4449	.4122	.4497	.4735	.2101	.3112	.0476	.0447	0.9325	0.9507	2
3	1.831	2.161	.4162	.3014	.4534	.3867	.3006	.4621	.0429	.0449	1.2462	1.1387	3
4	1.870	2.270	.4089	.2744	.4513	.3946	.2921	.4513	.0340	.0439	1.2088	1.0929	4
5	1.880	2.162	.4168	.2837	.4501	.3772	.2811	.4706	.0420	.0416	1.1456	1.1505	5
6	1.814	2.061	.4572	.3643	.4775	.4336	.2512	.3610	.0375	.0429	1.0361	1.0207	6
7	1.781	2.024	.4327	.3546	.4284	.4119	.3220	.3807	.0398	.0560	1.0450	1.0316	7
8	1.742	1.881	.4431	.4239	.4582	.4534	.2702	.2722	.0376	.0599	1.0788	1.0642	8
9	1.830	2.023	.4064	.3502	.4493	.4131	.2713	.3813	.0372	.0406	1.1987	1.1381	9
10	1.804	1.904	.4193	.3403	.4332	.4114	.3070	.3224	.0355	.0476	1.0494	1.0570	10
11	1.751	1.871	.4315	.4194	.4646	.4477	.3212	.3040	.0480	.0458	0.9632	0.9374	11
12	1.742	1.803	.4260	.4153	.4405	.4485	.2201	.2615	.0402	.0423	0.9995	1.0050	12
13	1.723	2.021	.3691	.3368	.3865	.3970	.3621	.4213	.0425	.0562	1.0368	1.0064	13
*	1.800	2.096	.4059	.3290	.....	.....	.....	.....	.....	.....	......	......	*
	Grain 1909						Straw 1909						
1	1.830	2.185	.4789	.3098	.4770	.3622	.2970	.4401	.0556	.0372	0.9101	0.9741	1
2	1.730	2.045	.4689	.4116	.4503	.4341	.2603	.3670	.0502	.0400	1.0070	0.9990	2
3	1.970	2.210	.4841	.3213	.4512	.3904	.2804	.4702	.0424	.0333	1.0061	1.2291	3
4	1.800	2.180	.4588	.2794	.4370	.3790	.3051	.4472	.0542	.0284	0.8462	1.0092	4
5	1.795	2.420	.4182	.2775	.4324	.3381	.2470	.5004	.0290	.0290	0.8814	1.0560	5
6	1.730	1.990	.4671	.3845	.4451	.3752	.2252	.3271	.0404	.0289	0.6732	0.7653	6
7	1.770	2.315	.4614	.2830	.4223	.3090	.2471	.5252	.0385	.0344	0.8821	1.0041	7
8	1.740	2.035	.4623	.3685	.4590	.4063	.2470	.3451	.0432	.0318	0.7680	0.9762	8
9	1.820	2.300	.4505	.2817	.4251	.3431	.2773	.4324	.0402	.0286	0.8124	1.0680	9
10	1.930	2.270	.4702	.2781	.4073	.3652	.2851	.5604	.0432	.0369	0.9403	1.2053	10
11	1.810	2.065	.4683	.4096	.4441	.4261	.2322	.4021	.0440	.0459	0.9431	1.2224	11
12	1.850	2.170	.4780	.4449	.4304	.4553	.2950	.4670	.0530	.0502	0.9723	1.0641	12
13	1.805	2.175	.4536	.3259	.4031	.3960	.3221	.5172	.0640	.0402	0.9760	1.1360	13
*	1.827	2.525	.4646	.2947	.....	.....	.....	.....	.....	.....	.....	.....	*

*Average of unfertilized plots.

TABLE XXIV—POUNDS OF NITROGEN, PHOSPHORUS AND POTASSIUM REMOVED PER ACRE BY WHEAT CROP AT STRONGSVILLE, 5-YEAR ROTATION FROM HALVES OF PLOTS RECEIVING LIME AND FLOATS, 1908 AND 1909—POUNDS

Treatment	Grain 1908						Straw 1908						Treatment
	Nitrogen		Phosphorus		Potassium		Nitrogen		Phosphorus		Potassium		
Plot No.	Floats	Lime	Floats	Lime	Floats	Lime	Floats	Lime	Floats	Lime	Floats	Lime	Plot No.
1	9.09	21.46	1.99	3.12	2.20	4.07	3.23	7.47	0.585	0.659	9.42	13.31	1
2	21.29	21.34	5.20	4.78	5.25	5.48	3.84	5.70	0.868	0.820	17.06	17.48	2
3	7.32	20.73	1.65	2.89	1.51	3.70	2.40	6.25	0.340	0.606	9.96	15.48	3
4	11.78	22.70	2.57	2.74	2.83	3.94	2.75	7.20	0.323	0.698	11.48	17.48	4
5	11.84	21.81	1.62	2.86	2.83	3.80	3.50	8.41	0.523	0.742	14.31	20.59	5
6	31.85	29.87	8.04	5.28	8.40	6.28	6.40	7.30	0.956	0.868	26.51	20.71	6
7	10.32	17.97	2.51	3.15	2.48	3.66	3.52	5.13	0.436	0.755	11.49	13.92	7
8	27.48	25.38	6.99	5.71	7.23	6.11	6.42	5.21	0.895	1.152	25.67	20.53	8
9	15.73	23.23	3.49	4.02	3.86	4.74	3.83	6.42	0.528	0.685	17.02	19.22	9
10	11.52	20.71	2.68	3.70	2.77	4.48	3.48	5.08	0.410	0.755	12.17	16.80	10
11	29.40	30.10	7.24	6.74	7.80	7.20	8.57	7.05	1.287	1.074	25.81	22.02	11
12	28.36	26.10	6.94	6.02	7.17	6.50	5.56	5.79	1.017	0.943	25.28	22.40	12
13	11.01	19.18	2.36	3.19	2.47	3.76	4.46	6.76	0.523	0.903	12.85	16.19	13
	Grain 1909						Straw 1909						
1	17.56	12.23	4.59	1.73	4.29	2.02	5.10	5.54	0.956	0.467	15.65	12.28	1
2	16.26	17.17	4.40	3.45	4.23	3.64	5.62	6.67	0.895	0.729	17.93	18.19	2
3	17.33	11.49	4.26	1.66	3.96	2.02	4.53	5.45	0.685	0.384	16.29	14.25	3
4	18.71	10.89	4.76	1.39	4.54	1.89	5.06	5.27	0.899	0.331	14.05	11.90	4
5	21.54	12.58	5.01	1.44	5.18	1.76	5.13	5.80	0.602	0.336	18.33	12.24	5
6	20.41	27.85	5.50	5.37	5.25	5.24	4.77	7.84	0.855	0.689	14.27	18.36	6
7	16.64	12.50	4.33	1.51	3.96	1.93	3.85	6.30	0.598	0.410	13.76	12.05	7
8	19.49	26.45	5.17	4.78	5.13	5.27	4.59	7.93	0.803	0.729	14.28	22.45	8
9	19.65	15.18	4.86	1.85	4.59	2.26	5.04	6.13	0.729	0.406	14.78	15.16	9
10	20.84	12.70	5.07	1.55	4.40	2.04	5.24	6.38	0.794	0.419	17.30	13.74	10
11	21.72	25.18	5.63	5.60	5.33	5.19	4.87	10.77	0.921	1.231	19.80	32.74	11
12	25.16	34.72	6.50	7.11	5.85	7.27	7.25	13.44	1.301	1.445	23.91	30.65	12
13	22.01	13.92	5.53	2.08	4.91	2.53	6.82	7.23	1.357	0.563	20.69	15.90	13

TABLE XXVII—POUNDS OF NITROGEN REMOVED PER ACRE BY WHEAT GRAIN AND STRAW, 5-YEAR ROTATION AT WOOSTER, 1902, 1904, 1905, 1906, 1907, 1908.—POUNDS

Year	Nitrogen removed by grain						Nitrogen removed by straw			
	1902	1904	1905	1906	1907	1908	1902	1904	1907	1908
Plot No.										
1	17.07	09 35	08 03	23.01	17.91	23.59	06.80	06.80	10.63	11.86
2	28 98	25.37	17.90	33 53	26 38	27.65	07.79	12.59	09.10	07.91
3	20.10	15 97	07 07	26.09	19.05	23.72	06.40	16.42	08.79	10.14
4	15.80	12.20	06 80	25.24	19.14	21.63	05.89	14.22	08.44	09.94
5	19.78	16.24	08.91	30.60	25 28	26.44	07.59	18.40	13.58	14.54
6	42.48	31.65	27 52	45.40	36.75	38.57	13 20	13.61	12.90	12.84
7	16.81	11.43	06 51	27 09	18.52	20.76	06.61	09.73	08.51	06.22
8	25.78	22.14	17.14	31.97	24.51	28.75	06.97	.....	87.99	08.89
9	21.25	15.76	08.25	37 12	23.05	28.46	08.13	15.51	11.54	14.02
10	13.85	10.75	06.23	27.62	15.45	24.78	10.30	09.64	06.15	09.16
11	43.97	31.39	30 44	48.68	33.32	44.58	11.76	14.40	12.38	16.07
12	49.31	35.93	36.15	50 88	42.38	47.03	15.28	18.08	16.46	16.80
13	14 43	11.96	06 07	21.90	15.65	22.94	05.81	12.96	06.88	08.53
14	41.90	33.80	31.93	43.10	32.50	41.29	12.36	13.79	13.12	11.77
15	46.17	33.57	27.24	46 50	29.96	35.73	11.90	15.18	11.92	10.34
16	14.72	11.55	05.02	26.80	15 76	16.09	06.07	09.91	07.92	06.76
17	35 71	....	22.23	43.50	28.47	31.91	10.22	10.38	10.31	08.97
18	30.75	30 62	22.59	46.75	33.88	32 66	09.16	14.50	13.54	09.56
19	.....	12.15	07 39	28 95	16 91	18.33	07.45	13.01	07.60	07.63
20	19.18	27 37	17 71	43 16	23 82	26 73	06.83	16.23	09.78	08.36
21	25 80	29.73	25.34	39.42	22.23	28.52	06.14	11.55	08.83	08.25
22	11 17	12.83	07.56	26 94	13.19	19.20	04.45	12.34	06.35	08.13
23	23.22	25.91	.....	37.58	19.49	29.71	05 59	10.46	07.01	07.79
24	20.87	26.46	24 37	41.15	24.36	31.51	04.99	10.06	10.32	08.69
25	11.49	12.94	08 32	27 32	12 89	19.41	04.29	14.30	06.59	09.62
26	34 45	30.18	22 25	45.35	28.18	33.28	07.98	18.08	11.37	10.11
27	35.10	.....	32 60	44.54	30.70	36.17	08.29	16.34	12.70	10.96
28	15.01	12 03	09.69	23.08	14.11	18 71	04.50	11.58	06.75	06.41
29	39.06	27.23	27.74	46.80	29.01	34.34	10.04	16.09	11.47	10.67
30	32.09	25.00	24.48	35.02	29.89	29 18	08.31	15.04	11.90	07.58

TABLE XXVIII—POUNDS OF POTASSIUM REMOVED PER ACRE BY WHEAT GRAIN AND STRAW FROM EAST AND WEST ENDS OF 5-YEAR ROTATION PLOTS AT WOOSTER, 1907 AND 1908

Plot No.	Grain				Straw			
	1907		1908		1907		1908	
	East end	West end	East end	West end	East end	West end	East end	West end
1	3.35	3.02	4.31	4.65	13.88	23.26	14.90	23.07
2	5.26	5.23	6.53	6.50	12.79	23.36	16.69	23.18
3	3.81	3.42	5.58	3.82	14.54	14.99	19.14	25.55
4	3.45	3.40	4.49	3.41	10.36	18.14	13.43	17.95
5	4.30	3.91	5.05	3.35	15.92	15.19	17.23	21.90
6	6.77	6.04	7.58	7.34	25.50	31.80	20.94	27.00
7	3.64	3.17	3.78	3.20	11.45	12.91	11.33	16.37
8	4.94	4.59	5.57	6.91	18.34	18.32	23.29	35.57
9	4.28	3.22	4.70	5.03	19.10	16.27	27.76	31.95
10	3.11	2.62	4.25	4.62	11.89	8.21	15.87	16.83
11	6.66	5.64	9.63	7.14	29.35	31.30	41.37	43.14
12	6.16	6.75	9.18	9.77	30.84	35.81	46.35	40.28
13	3.30	2.67	4.19	5.35	11.01	9.70	14.66	17.11
14	6.10	5.77	8.47	8.32	23.28	25.19	34.90	39.37
15	5.59	5.22	7.26	7.30	24.41	25.79	28.00	32.34
16	3.49	2.80	3.54	3.02	12.69	10.68	13.11	14.00
17	6.06	5.33	6.80	8.40	22.06	24.18	27.24	36.65
18	7.09	6.14	6.78	8.05	26.55	27.58	25.67	31.68
19	3.67	3.01	3.57	3.73	12.21	.....	11.40	15.45
20	4.55	6.01	5.58	5.15	20.31	21.30	22.67	21.22
21	4.39	5.23	6.48	7.44	19.52	22.73	23.38	32.77
22	2.94	2.63	3.18	3.86	9.47	11.18	10.16	15.90
23	4.35	4.70	6.36	7.14	15.13	19.00	21.39	34.48
24	5.28	5.57	6.12	7.50	25.88	23.21	24.49	36.71
25	2.69	2.65	3.36	4.44	8.77	11.06	13.27	18.76
26	6.09	5.63	6.34	7.24	24.03	21.12	30.72	30.52
27	6.36	5.51	....	7.58	27.52	29.95	35.63	29.87
28	3.08	2.43	3.65	4.35	11.19	9.48	11.95	12.38
29	6.03	5.17	8.66	5.84	27.46	21.21	38.39	26.47
30	6.35	6.11	8.54	5.29	23.04	27.28	30.54	25.83

TABLE XXIX—POUNDS OF PHOSPHORUS REMOVED PER ACRE BY WHEAT GRAIN AND STRAW, 5-YEAR ROTATION AT WOOSTER, 1904, 1907 AND 1908

Year	Grain					Straw					Year
	1904	1907		1908		1904	1907		1908		
Plot No.		East end	West end	East end	West end		East end	West end	East end	West end	Plot No.
1	1.41	2.72	2.83	3.98	4.23	0.92	1.24	1.34	0.99	1.39	1
2	4.68	5.62	5.47	6.35	0.46	1.42	1.82	1.33	0.82	1.20	2
3	2.46	3.37	3.46	4.41	4.14	1.65	0.93	0.96	0.99	1.12	3
4	1.94	2.93	3.14	4.32	3.88	1.30	0.76	1.20	1.25	1.04	4
5	2.41	3.47	3.40	4.67	3.25	1.56	1.28	1.19	1.47	1.10	5
6	6.02	6.99	6.13	7.66	6.63	2.20	1.92	1.67	1.10	1.44	6
7	2.03	3.03	2.91	3.79	3.94	1.15	0.90	1.07	0.54	0.70	7
8	5.05	5.11	4.86	5.85	7.28	1.74	1.68	1.06	0.81	0.98	8
9	2.54	3.52	2.83	4.20	4.34	1.79	1.30	1.06	1.22	1.14	9
10	1.92	2.61	2.23	3.83	4.40	1.09	0.67	0.70	0.79	0.87	10
11	6.25	6.29	5.47	8.57	8.12	2.96	1.57	1.42	1.65	1.54	11
12	6.33	5.83	7.05	8.39	7.71	2.88	1.55	2.13	1.55	1.31	12
13	2.02	2.65	2.09	3.65	4.65	1.40	0.77	0.78	0.89	0.72	13
14	6.61	5.58	5.10	8.04	7.57	1.53	1.17	1.69	1.06	1.17	14
15	6.32	4.82	4.48	6.55	6.59	2.13	1.13	1.34	0.96	1.00	15
16	2.13	2.67	2.08	3.13	2.72	1.08	. ..	0.89	0.78	0.68	16
17	. ..	4.99	5.08	7.12	7.56	2.08	1.81	1.30	1.02	1.10	17
18	6.55	7.20	5.90	7.42	7.45	2.98	2.17	1.67	1.37	1.13	18
19	2.25	3.50	2.24	3.40	3.31	1.71	0.72	0.73	0.86	0.75	19
20	5.47	5.07	4.02	5.79	5.10	2.54	1.01	1.17	1.00	0.72	20
21	6.68	4.55	4.69	6.71	7.31	1.72	1.07	1.15	0.98	1.09	21
22	2.37	2.26	1.98	2.90	3.70	1.38	0.51	0.76	0.78	0.92	22
23	6.29	4.13	4.32	6.33	7.97	2.00	1.08	1.09	1.03	1.06	23
24	5.78	5.24	4.90	5.99	8.19	2.03	1.73	1.21	0.98	1.14	24
25	2.39	2.10	1.98	3.09	4.05	1.68	0.56	0.89	1.05	1.10	25
26	6.50	5.18	5.02	6.20	6.69	2.51	1.44	1.21	1.28	1.06	26
27	. ..	6.18	5.02	7.84	7.36	2.63	1.78	1.37	1.17	1.06	27
28	2.17	2.98	1.92	3.40	4.00	1.32	....	0.91	0.54	0.87	28
29	5.43	5.84	4.76	8.87	5.66	2.30	1.64	1.07	1.25	1.13	29
30	5.45	6.09	5.74	8.91	6.31	2.57	1.84	2.00	1.37	0.99	30

TABLE XXX—RATIO OF PHOSPHORUS TO NITROGEN. PARTS OF PHOSPHORUS TO 100 PARTS OF NITROGEN. EAST END 5-YEAR ROTATION AT WOOSTER, 1908

Plot No.	Fertilizing elements per acre for one 5-year rotation			Parts of phosphorus to 100 parts of nitrogen		Plot No.
	Phosphorus	Potassium	Nitrogen	Grain	Straw	
	Lbs.	Lbs.	Lbs.			
1	..	....	...	18.59	10.60	1
2	20	....	...	24.18	12.83	2
3	..	108	...	19.51	11.00	3
4	..	....	..	20.69	14.05	4
5	..	....	76	17.11	10.04	5
6	20	....	76	20.12	10.60	6
7	..	....	...	19.95	11.17	7
8	20	108	...	25.36	12.39	8
9	..	108	76	15.41	9.25	9
10	..	....	...	16.72	8.99	10
11	20	108	76	18.59	9.91	11
12	20	108	114	18.20	9.03	12
13	..	....	...	18.24	10.82	13
14	15	75	51	20.25	10.60	14
15	10	41	25	19.60	10.21	15
16	..	...	...	20.08	11.78	16
17	30	108	38	25.97	13.44	17
18	48	112	144	24.79	15.67	18
19	..	....	...	21.74	13.27	19
20	24	56	72	23.57	10.95	20
21	30	108	38	25.97	13.35	21
22	..	....	...	19.21	11.56	22
23	30	108	38	25.89	15.23	23
24	30	108	38	24.14	13.14	24
25	..	....	...	18.59	11 17	25
26	20	108	76	18.59	10.30	26
27	20	108	76	21.26	10.39	27
28	..	....	...	20.03	10.43	28
29	20	108	76	22.48	11.83	29
30	30	108	38	25.71	15.58	30

TABLE XXXI: PERCENTAGE INCREASE YIELD AND PERCENTAGE INCREASE PHOSPHORUS REMOVED BY WHEAT CROP ON FERTILIZED PLOTS, 5-YEAR ROTATION AT WOOSTER

Plot No.	Grain 1907				Straw 1907				Plot No.
	East end		West end		East end		West end		
	Increase yield	Increase phosphorus removed	Increase yield	Increase phosphorus removed	Increase yield	Increase phosphorus removed	Increase yield	Increase phosphorus removed	
2	61.27	101.25	60.82	86.18	53.23	70.61	48.34	3.03	2
3	13.64	17.83	1.88	13.77	18.69	2.39	—3.12	—22.37	3
5	21.31	17.08	18.39	11.09	41.49	58.06	13.60	3.00	5
6	106.08	133.04	94.47	105.25	134.78	124.48	90.08	49.60	6
8	42.81	77.03	63.86	81.59	47.28	105.31	54.83	10.95	8
9	39.54	27.93	15.38	15.27	41.82	74.26	33.16	27.89	9
11	116.44	139.53	135.54	150.09	143.13	123.60	204.50	95.80	11
12	107.90	120.46	208.40	230.00	139.61	111.24	239.40	182.08	12
14	92.16	109.67	135.13	144.05	113.38	......	155.26	95.21	14
15	77.83	80.68	122.50	115.06	85.80	......	156.05	57.14	15
17	78.53	69.58	100.85	137.55	75.66	......	137.56	55.20	17
18	92.15	123.88	128.58	169.32	108.75	......	154.28	112.77	18
20	45.97	65.90	80.22	86.46	79.34	56.37	116.29	58.23	20
21	44.75	72.11	92.49	126.52	75.37	84.96	108.82	52.60	21
23	49.38	87.35	87.00	118.28	53.46	104.95	79.01	44.02	23
24	90.82	143.11	119.31	147.90	154.35	217.60	103.72	43.29	24
26	102.48	117.39	143.38	156.34	136.07	......	107.76	53.59	26
27	111.62	131.15	157.44	158.42	139.43	......	183.32	96.87	27
	Grain 1908				Straw 1908				
2	45.18	54.01	42.97	56.77	28.41	—23.57	16.98	—5.46	2
3	8.28	4.97	8.43	3.48	5.48	—14.60	—1.09	—3.38	3
5	20.00	12.63	—.94	—16.55	35.37	49.11	15.76	18.86	5
6	93.92	92.96	78.85	68.96	105.14	46.51	69.09	77.00	6
8	31.71	53.54	58.12	77.82	53.15	30.06	49.67	29.88	8
9	17.90	9.69	14.51	2.36	43.83	73.45	33.77	40.64	9
11	112.79	127.16	76.69	81.20	103.42	100.00	85.13	87.76	11
12	115.60	125.58	68.64	68.92	118.72	81.21	88.17	71.59	12
14	126.14	130.53	88.09	90.55	96.96	24.48	121.70	64.63	14
15	99.02	97.50	102.13	97.64	85.51	18.08	87.46	42.85	15
17	96.07	120.70	128.79	158.12	90.06	18.08	113.94	54.26	17
18	96.46	123.97	99.71	138.40	78.80	64.92	72.27	54.43	18
20	65.92	79.08	46.85	48.10	69.50	20.94	28.08	—11.29	20
21	86.75	118.94	65.39	143.90	72.20	21.62	51.42	25.00	21
23	78.33	113.38	70.47	108.68	54.71	19.09	52.19	7.52	23
24	71.87	97.41	81.86	108.20	55.80	3.19	61.95	9.58	24
26	89.66	93.72	57.15	65.72	68.47	48.48	36.93	3.38	26
27	116.67	137.51	72.91	82.96	132.19	69.18	71.35	11.87	27

TABLE XXXIII.—PERCENTAGE INCREASE YIELD AND PERCENTAGE INCREASE POTASSIUM REMOVED BY WHEAT CROP ON FERTILIZED PLOTS, 5-YEAR ROTATION AT WOOSTER

Plot No.	Grain 1907				Straw 1907				Plot No.
	East end		West end		East end		West end		
	Increase yield	Increase potassium removed	Increase yield	Increase potassium removed	Increase yield	Increase potassium removed	Increase yield	Increase potassium removed	
2	61.27	55.39	60.82	66.49	53.23	1.18	48.34	86.06	2
3	13.64	11.65	1.88	4.82	18.69	26.77	—3.12	—24.27	3
5	21.31	22.69	18.39	17.70	41.49	48.33	13.60	—6.96	5
6	106.08	89.76	94.47	86.18	134.78	129.94	90.08	118.23	6
8	42.81	42.68	65.86	53.61	47.28	57.40	54.83	61.09	8
9	39.54	30.30	15.38	14.74	41.82	61.92	33.16	66.10	9
11	116.44	109.66	135.54	113.83	143.13	153.11	204.50	259.73	11
12	107.90	90,25	208.40	154.06	139.61	172.76	239.40	288.90	12
14	92.16	81.48	135.10	112.53	113.38	101.21	155.26	150.95	14
15	77.83	68.19	122.50	89.45	85.80	101.23	156.05	148.95	15
17	78.53	70.79	100.85	85.54	75.66	76.14	137.56	132.11	17
18	92.15	96.32	128.58	109.03	108.75	114.63	154.28	171.84	18
20	45.97	32.92	80.22	74.06	79.34	79.39	116.29	106.60	20
21	44.75	37.76	92.49	89.75	75.37	87.48	108.82	111.59	21
23	49.38	52.32	87.00	78.30	53.46	63.79	79.01	70.43	23
24	90.82	90.71	119.19	111.32	154.35	187.37	103.72	108.81	24
26	102.48	100.54	143.38	119.03	136.07	150.86	107.66	99.68	26
27	111.62	86.82	157.44	119.86	139.43	164.98	183.32	198.42	27
	Grain 1908				Straw 1908				
2	45.18	49.33	42.97	53.52	28.41	14.31	16.98	8.17	2
3	8.28	3.37	8.43	.65	5.48	36.91	—1.09	29.60	3
5	20.00	18.94	—.94	.24	35.37	32.43	15.76	25.91	5
6	93.92	88.84	78.85	128.17	105.14	70.29	69.09	60.35	6
8	31.71	41.26	58.12	88.88	53.15	81.14	49.76	115.86	8
9	17.90	15.01	14.51	19.30	43.83	93.18	33.77	91.72	9
11	112.79	118.82	76.69	42.07	103.42	167.61	85.13	154.08	11
12	115.60	118.14	68.64	87.69	118.72	207.71	88.17	135.99	12
14	126.14	112.70	88.09	83.69	96.96	145.56	121.70	144.30	14
15	99.02	94.49	102.13	95.55	85.51	104.36	87.46	114.25	15
17	96.07	90.90	128.79	161.06	90.06	117.14	113.94	150.00	17
18	96.46	90.00	99.71	129.45	78.80	114.42	72.27	109.21	18
20	65.92	62.16	46.85	35.88	69.50	106.42	28.08	35.95	20
21	86.75	95.25	65.39	94.58	72.20	121.28	51.42	107.95	21
23	78.33	95.90	70.47	75.86	54.71	91.74	52.19	104.78	23
24	71.87	85.89	81.86	76.56	55.80	100.81	61.95	106.34	24
26	89.66	86.02	57.15	64.21	68.47	138.09	36.93	85.05	26
27	116.67	......	72.91	72.58	132.19	185.96	71.35	107.85	27

TABLE XXXIII:—PERCENTAGE INCREASE YIELD AND PERCENTAGE INCREASE NITROGEN REMOVED BY WHEAT CROP ON FERTILIZED PLOTS, 5-YEAR ROTATION AT WOOSTER

Plot	Grain 1907				Straw 1907				Plot
	East end		West end		East end		West end		
No.	Increase yield	Increase nitrogen removed	Increase yield	Increase nitrogen removed	Increase yield	Increase nitrogen removed	Increase yield	Increase nitrogen removed	No.
2	61.27	45.82	60.82	42.38	53.23	1.22	48.34	—15.45	2
3	13.64	7.83	1.88	—3.50	18.69	—5.28	—3.12	2.32	3
5	21.31	32.83	18.39	33.95	41.49	83.85	13.60	42.91	5
6	106.08	105.05	94.47	88.73	134.78	68.53	90.08	38.24	6
8	42.81	35.26	65.86	44.73	47.28	9.63	54.83	—3.15	8
9	39.54	53.14	15.38	27.02	41.82	85.17	33.16	46.65	9
11	116.44	114.18	135.54	115.20	143.13	90.22	204.50	96.27	11
12	107.90	129.17	208.40	220.57	139.61	118.92	239.40	180.22	12
14	92.16	93.14	135.13	123.37	113.38	87.53	155.26	73.69	14
15	77.83	76.93	122.50	107.05	85.80	51.36	156.05	63.01	15
17	78.53	73.72	100.85	78.88	75.66	40.92	137.56	23.38	17
18	92.15	97.50	128.58	113.87	108.75	80.75	154.28	71.60	18
20	45.97	39.41	80.22	65.88	79.34	41.08	116.29	32.04	20
21	44.75	34.76	92.49	76.70	75.37	39.32	108.82	23.94	21
23	49.38	37.36	87.00	61.48	53.46	26.49	79.01	—3.20	23
24	90.82	80.05	119.31	95.18	154.35	114.33	103.72	18.60	24
26	102.48	99.23	143.38	125.32	136.07	111.80	107.76	37.29	26
27	111.62	109.25	157.44	143.65	139.43	92.72	183.32	87.04	27
	Grain 1908				Straw 1908				
2	45.18	23.64	42.97	17.89	28.41	—31.33	16.98	—28.99	2
3	8.28	7.49	8.43	5.53	5.48	—.33	—1.09	—7.17	3
5	20.00	33.76	—.94	14.75	35.37	96.78	15.76	46.89	5
6	93.92	93.44	78.85	74.38	105.14	69.72	69.09	77.31	6
8	31.71	13.84	58.12	43.63	53.15	8.07	49.67	37.45	8
9	17.90	26.30	14.51	22.92	43.83	78.86	33.77	67.98	9
11	112.79	110.02	76.69	62.91	103.42	92.92	85.13	66.95	11
12	115.60	119.66	68.64	83.99	118.72	105.48	88.17	80.15	12
14	126.14	114.37	88.09	89.15	96.96	30.42	121.70	64.95	14
15	99.02	96.07	102.13	93.83	85.51	31.93	87.46	49.00	15
17	96.07	74.88	128.79	102.61	90.06	15.32	113.94	37.31	17
18	96.46	90.92	99.71	81.42	78.80	34.30	72.27	26.71	18
20	65.92	58.61	46.85	32.88	69.50	39.66	28.08	—16.33	20
21	86.75	68.82	65.39	38.28	72.20	10.32	51.42	—1.29	21
23	78.33	56.79	70.47	52.39	54.71	—10.67	52.19	—8.22	23
24	71.87	53.78	81.86	70.03	55.80	—11.21	61.95	1.44	24
26	89.66	98.56	57.15	53.50	68.47	57.86	36.93	—14.41	26
27	116.67	118.67	72.91	69.34	132.19	75.07	71.35	27.49	27

THE MINERAL NUTRIENTS IN BLUE-GRASS

OHIO Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., DECEMBER, 1910

BULLETIN 222

The Bulletins of this Station are sent free to all residents of the State who request them. When a change of address is desired, both the old and the new address should be given. All correspondence should be addressed to EXPERIMENT STATION, Wooster, Ohio.

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BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 222 DECEMBER, 1910.

THE MINERAL NUTRIENTS IN BLUE-GRASS

BY E. B. FORBES, A. C. WHITTIER, AND R. C. COLLISON.

Grass and exercise are usually considered essential for the normal development of bone and muscle in live-stock; but not all grass will grow sound bone. In all extensive countries, including the United States, where live-stock raising is generally followed, there are regions where grazing animals suffer from malnutrition of the bones. The commonest form of this disease responds readily to treatment with bone-flour and other preparations containing calcium and phosphorus, and is invariably associated with abnormal composition of the range or pasture grass.

These facts are established. At the same time, however, there is a prevalent idea in the United States that animals generally get as much mineral matter in the food as they need, especially if they have access to pasture grass, and with this sweeping assumption the subject is usually dismissed by farmers and by teachers of agriculture as outside the field of practical interests.

With an idea that this attitude may have led us to overlook a somewhat important matter, the authors have examined samples of blue-grass selected from a number of localities in the various distinctive soil areas of this State, having in mind especially food-values rather than fertility considerations.

While the mineral content of vegetable crops is without doubt the resultant of a considerable number of varying factors, the most important of these is the composition of the soil. If a certain type of soil, or method of treatment, produces blue-grass of a certain corresponding composition, it is important that we demonstrate the facts, and point out their probable bearing on stock raising. In

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 223 NOVEMBER, 1910

FOREST CONDITIONS IN OHIO

FOURTH ANNUAL REPORT

REPORT OF THE DIRECTOR

MR. JOHN COURTRIGHT, *President of the Board of Control:*

SIR:—I have the honor to submit herewith the fourth annual report of the operations of the Department of Forestry of this Station for the year ending November 15, 1910.

Next to the soil, the original forests of Ohio constituted its greatest natural asset, far outranking in potential value its combined mineral resources. To the pioneer farmer, however, the forest was but a cumberer of the ground, and his greatest problem was to get it out of his way. Regarded from the standpoint of the physical welfare of the nation as a whole, it would seem to have been better if the prairie states had been settled first, thus leaving the great store of splendid timber which was wastefully destroyed in Ohio and Indiana to be drawn upon as needed for useful purposes. As the matter stands, however, the pioneer's point of view has descended from generation to generation, and those who now realize the loss which has been suffered have the two-fold task before them of overcoming settled habits of thought and convincing the land owners of the potential value of the forest, and of pointing out to him a practicable method by which to restore a part of his area t forest conditions.

How to accomplish this work of demonstration most effectively is the great forestry problem in Ohio, and all the work of the Forestry Department of the Experiment Station has had this end either directly or indirectly in view.

All experience has shown that the most effective method of overcoming fixed habits of thought, and for most persons the only method, is by personal explanation and actual demonstration. "Men are but children of a larger growth," and most men, like most children, require a personal teacher. The printing press is a most useful adjunct to the means of diffusing knowledge; but the printing press alone is inadequate. There must be more personal teaching of forestry if it is to make appreciable headway.

It is the province of the College of Agriculture, through its Forestry School, to provide such teaching; but before this school can accomplish its purpose for Ohio there must be accumulated a body of accurate knowledge respecting forest conditions in the state. This accumulation of knowledge is the province of the Experiment Station, and the only method by which such knowledge can be accumulated is through the study of existing forests and the actual work of reforestation on the various soil types of the state under conditions of absolute control.

The forest survey, which has been conducted on a small scale for several years, is the first step in this direction and this survey has been found a most effective method of attracting the attention and securing the interest and cooperation of land owners through whose possessions it was being conducted. The survey has forcibly brought out the fact that the average forest owner in Ohio possesses no knowledge of the foundation principles of successful forest management, and that when he attempts to improve his woodland he usually takes exactly the opposite from the proper method. The conditions governing forest growth are wholly different from those which obtain in the production of field crops and orchard fruits, and the failure to observe these conditions is the more fatal in the case of the forest because of the longer time required for the forest to come to maturity. It is therefore of the utmost importance that correct information in forest production be placed before the forest owners of the State at the earliest possible date, and no method of imparting such information is so effective as actual demonstration in the woodlot under the guidance of men who have been technically trained in the work of forestry. It is much to be desired that the survey might be pushed forward with much greater rapidity than has been possible with the resources hitherto at the command of the Station.

Through the cooperation of a number of public institutions the Station has been enabled to secure opportunities for both research and demonstration, under conditions favorable to continuity of work, a matter of first importance in dealing with problems in which the time element is so important a factor as in forestry. It is believed that such cooperation may be made mutually advantageous.

LEGISLATION NEEDED

Throughout the hilly regions of the state there are large areas of steep hillside land bordering the streams, much of which has been denuded of its natural forest growth, but all of which is unfit for cultivation because of its topography. Much of this land is held at a nominal value, being practically worthless in its present condition, and yet it is capable of producing an income which it is believed would compare favorably with that derived from the more level lands, if it were protected from fire and put under well informed management.

Section 7496, of the General Code of Ohio, authorizes township trustees to call on the inhabitants of the township to assist in extinguishing forest or prairie fires, but this method is entirely inadequate, as a fire is likely to have caused great damage before the machinery for its control can be put in operation. Some provision should be made for a systematic patrol of the regions liable to forest fires during the small part of the year when there is danger from such fires. The necessary cost of such a patrol would be far less than the present annual loss from fires. Such surveillance, and the acquisition by the state of lands along streams to be held for the double purpose of reducing flood ravages and of serving as object lessons in forestry, would seem to be questions worthy of careful study by legislators.

Respectfully submitted,

CHAS. E. THORNE, *Director.*

FOREST CONDITIONS IN OHIO

REPORT OF THE CONSULTING FORESTER

By W. J. GREEN

TRIALS OF ORNAMENTAL TREES AND SHRUBS AT PUBLIC INSTITUTIONS

The law establishing the department of forestry at the Station specifies as one of the duties of the Station under the act "to determine the kinds of trees and shrubs best suited to various situations for windbreaks and shelter, for beautifying grounds, and the best methods of planting and managing the same."

This does not broaden the field sufficiently to include all that belongs to landscape architecture, but simply authorizes a study of ornamental trees and plants, to determine their adaptability to certain purposes and under what cultural and climatic conditions each succeeds best. Since many trees are used for both ornamental and forestry purposes it is plain that such species may be studied from the two standpoints at the same time and in the same place.

Work of this kind requires duplication in various sections of the state, upon different kinds of soil and under unlike climatic conditions.

Futhermore, the long-time element enters into work of this nature to such an extent that much of it will be lost if the trials cannot be carried on for a considerable period.

This is not easily done, unless the land where the trees are planted is under the control of the Station, or upon the property of some permanent institution.

To put trees into the hands of private parties with an understanding that reports as to behavior and hardiness are to be made would bring only meager returns.

All state and educational institutions do more or less ornamental planting, and most of them are able to give the necessary care to trees furnished for this purpose. Since these institutions are on a permanent basis their grounds afford good opportunities to do permanent planting. Furthermore, these institutions are established in different sections of the state, and upon soils of varying character, thus affording all the conditions needful to make satisfactory trials.

The Station is now carrying on forestry work at a number of public institutions, and testing the value of ornamental trees will not add greatly to the work.

Work of this kind at public institutions has an added value because it is illustrative as well as experimental.

It not only serves to acquaint the people with the best species and varieties of trees and shrubs, but arouses an interest in them thus having an influence in favor of forestry.

The richness of our own tree flora may, in this manner, be well shown, also the importance of using native trees to a greater extent than is commonly done. The design is not to plant native trees exclusively, but to make a trial of many foreign species. It is now coming to be understood that foreign species and horticultural varieties have been given undue prominence in ornamental planting and trials of these much extolled sorts in comparison with native trees are much needed in order to clear up misconceptions in the mind of the public.

It is the practice of the Station to furnish none but small seedling trees to the various institutions. These are grown in nurseries for two or three years before planting in permanent quarters. Smaller trees are used than are commonly planted, but the cost is thus reduced and the mortality greatly lessened. In every way are the results better than by the usual method of planting large trees, brought from a distance.

It is not the purpose of the Station to do landscape gardening at the institutions, but to furnish some of the material to be used in such work, in order that different species and varieties may be put to a practical test and their value determined.

The Station can, in the beginning, offer suggestions as to the value of certain species, and gradually increase the fund of knowledge on this subject. Its reports on trees and shrubs will be enhanced by the opportunities thus afforded.

COOPERATION WITH CITIES IN FORESTRY WORK AND STUDIES OF ORNAMENTAL TREES

In cooperation with cities it is the purpose to make a study of shade trees, iucluding the species most desirable, also the inimical as well as favorable conditions under which they are placed.

The inquiry will be chiefly along horticultural and forestry lines and will relate mostly to selection of species, adaptation to soil and local conditions, methods of planting and care.

Much of the mortality of trees in cities is due to unfavorable environment, but in many cases it is possible to remedy the bad conditions.

A careful study of the situation needs to be made in order to make tree growing in cities more successful.

It is hoped, also, to awaken an interest among city people in forest parks. If such parks could be established in suburban, or outlying districts, much could be done in them to help along the cause of forestry. Such parks should be as near like natural forests as possible, consistent with the uses to which they are to be put. This would give opportunity to illustrate forest management and help greatly in solving forest problems. They would be useful, also, in awakening an interest in forestry and in affording means of nature study along many lines.

Creating sentiment in favor of forestry and promulgating right ideas concerning it is a proper mission for all citizens, whether dwellers in the city or country. Equalizing stream flow; lessening the force of winds; protection of birds; increasing the beauty of the landscape and the production of useful timber are offices of the forests, in which benefits all citizens have a share, hence the propriety of every one, whether land owner or not, doing what he can to help the cause.

European cities have made their forests good investments. We might leave out of consideration, altogether, the financial side of the matter, and yet a forest maintained by a city might pay even better here than abroad, because of influences coming from it which are in no way associated with money getting.

The Station can help greatly in establishing and carrying on such work by cities. The work, as far as the Station is concerned, would proceed along similar lines to those already started at public institutions. Some interest is manifest in several sections and work in cooperation with one city has been started.

FOREST CONDITIONS IN OHIO

REPORT OF THE FORESTER

EDMUND SECREST

FOREWORD

Interest in forestry in Ohio is increasing. The long-time element in forestry operations has prevented rapid development and enthusiasm at the outset. Limitations in our knowledge of silviculture have, in some cases, checked progress which would have been given impetus, had definite knowledge been at hand. The slowness of progress in moulding public sentiment, and in increasing the acreage of forest under conservative management, is therefore not a discouraging feature, but rather indicates that whatever progress is made, is something stable and for all time. The question is no longer whether forestry has communal value. This point is established. But it is one of procedure. It is a problem of methods.

The facts, which have been marshalled through the work of the forest service in Ohio, have etched themselves into the settled convictions of the people, so that today we have an enlightened public opinion upon the necessity of forestry as a factor in the future of our commonwealth, and one not based upon mere rhapsodies and sentimentality. Therefore at the present day, it seems our province to determine specific means for furthering forestry development, and to put into operation those policies which prove to be practicable.

Experimentation must be the paramount factor in Ohio forestry for the present, and the facts thus developed will serve as a nucleus for its growth. Thus there will be progress without danger of ultimate retrogression or depression.

LINES OF WORK

The chief lines of work covering the period from October 1, 1909 to October 1, 1910, in which the Station has been active are:

1. Cooperation with public institutions, possessing land, in the management of timber tracts, and the establishment of experimental and demonstration plantations.
2. Cooperation with private owners in the improvement of the farm woodlot and in various operations of reforestation.
3. The establishment of nurseries for experimental purposes and the distribution of forest-tree seedlings in connection with the various operations of cooperative work.
4. A forest survey, which includes a study of forest conditions throughout certain portions of the state.
5. Educational work, conducted through farmer's institutes, granges, picnics, exhibits at fairs and work at educational institutions.

COOPERATION WITH STATE INSTITUTIONS

Nearly all the state institutions of Ohio have farms in connection, and on some of them there are considerable areas of non-agricultural land, which is well suited to various forestry operations. This condition is not only true of state institutions, but of county, educational, municipal and private institutions as well.

These areas offer excellent opportunities for forestry, owing to the permanence which they insure. They are particularly suited to those phases of work which require long periods of time to produce results. Twelve institutions of various classes within the state have asked the Station to inaugurate forestry work on their farms, and on ten, work has been started, or the preliminary inspections made.

During the summer of 1910, maps and plans were made for forest tracts at the following institutions: Kenyon College at Gambier; the State Sanitorium at Mt. Vernon; the Boys' Industrial School at Lancaster, and the Hospital for the Criminal Insane at Lima. In all cases topographic maps were made, and detailed plans presented, subject to the approval of the institution authorities. The plans for operations and, in some cases, seedling trees, are furnished by the Station, all labor being provided by the cooperator.

Where considerable field supervision is required the Station provides a foreman for the purpose, as in the case of the Boys' Industrial School.

A white oak woodland. The trees are of original growth and will soon deteriorate because of change of forest conditions.

TRACT OF THE BOYS' INDUSTRIAL SCHOOL

LOCATION AND AREA

This tract, consisting of 1,230 acres, is located in Fairfield county, six miles south of the city of Lancaster.

GEOLOGY

Topography. The entire area lies in the extreme western limits of the great Appalachian Plateau and the topography, in consequence, is diversified. Irregular coves and ridges, typical of the Appalachian Mountain system, form the surface features. Arney creek, flowing through the north-west portion, is the principal stream. The glacial drift extends through this section, depositing granitic boulders and the clays peculiar to its character. The latter usually cap the ridges.

Rock. The Waverly Conglomerates and the Drift boulders form the principal rocks, the former being a coarse sandstone, and the latter mostly granites and quartzites. The brows of the ridges are frequently capped with the Waverly sandstones.

Soil. The soil is a mixture of the Drift clays and the debris of the Waverly sandstones and shales, with a considerable admixture of iron. A fertile, sandy loam, becoming black in places, and occurring toward the bottom of coves and exposures may be found in certain localities. In other places the sand is almost pure, resulting from the decomposition of a soft sandstone. The soil originally possessed considerable fertility. Certain areas have been severely cropped in times past, and in consequence are now comparatively sterile.

THE FOREST

The forest area comprises between 500 and 600 acres, including most of the steeper slopes and smaller coves. The original stand consisted of white, black, chestnut, scarlet and red oaks, tulip poplar, chestnut, pignut hickory, red maple, black gum, large toothed poplar, iron wood, dog wood, sassafras, pitch and Jersey (scrub) pine. Practically the entire area was cut over between twenty and sixty years ago, and the wood utilized in the production of charcoal, which was used in the reduction of iron ore.

The present forest, in consequence, is second growth of both seed and sprout origin. In the original forest composition, white oak formed a considerable percentage of the stand. But in the second generation, the black, scarlet and chestnut oaks superceded the white oak, both through their prolific seeding propensity, and greater rate of growth. On the oak slopes containing even-aged stands, the white oak is invariably suppressed by the black and

scarlet oaks, and unless relieved by the removal of the two latter, will soon be eliminated from the forest. The black and scarlet oaks are inferior as to quality and in some cases are almost worthless. In the majority of cases they are of sprout origin and are susceptible to decay at the butt. The chestnut and tulip poplar, seeking the protection of the moist slopes and coves, seem especially well adapted to this region and may be considered the best revenue producers among the forest trees. The chestnut oak occupies the tops of ridges or the immediate slopes. It developes rather slowly, and its uncertain commercial value limits its use to ties, and in some cases post material.

FOREST TYPES

The forest may be classified into five rather sharply defined types:

Oak Slope. Containing white, black and scarlet oak, and occasionally an admixture of chestnut oak, chestnut, tulip poplar and pignut hickory.

Chestnut Oak Ridges: Usually a composition of pure chestnut oak stand with an occasional black oak, chestnut, pitch and Jersey pine.

Cove Type: Composed of tulip poplar and chestnut, with occasional groups of large-toothed poplar. Fertile soil prevails, and on eastern and northern exposures the type is characterized by good height growth.

Creek Type: Seldom occuring. Usually characterized by willow, sycamore, red maple, alder and hazel bush. Occupies narrow valleys of creeks.

Old Field: Areas at one time under cultivation, but which have been abandoned. In case of forest reversion, pitch and Jersey pines, persimmon or sassafras usually take possession. The soil of old fields is more or less eroded and improverished. This type is quite common and offers good opportunities for experimental work in reforestation.

OPERATIONS UNDERTAKEN

Initial forestry operations were undertaken on this tract in 1907, when an old field planting of about 15 acres was made. This work was continued from year to year. Different species of trees were planted under different conditions of site and soil, spacing and mixtures.

Operations involving the management of the forest have also been undertaken. Thinnings and clear cuttings have been made, and reinforcing and reafforestation have been carried on. During the winter of 1909-10, about 10 acres, comprising an inferior stand of black, scarlet, chestnut and white oaks, chestnut and tulip poplar were clear cut. This area had suffered the effects of repeated fires

and in consequence many of the trees were fire scarred, diseased or dead. Coppice and other undesirable reproduction was taking possession. A portion of the area was planted to white pine, in the spring of 1910. The remainder will be planted the coming spring.

About 30,000 trees have been used in planting operations. Plantations were established in such a manner as to afford experimental data. Catalpa and locust were used to considerable extent at the outset. At least 10,000 pine and Norway spruce will be planted in the spring of 1911. White, red, ponderosa, Scotch and Austrian pines will be used, with the greatest number of the first named.

TRACT OF THE TUBERCULOSIS SANITORIUM

LOCATION AND AREA

This tract, consisting of 350 acres, is located in Knox county, three miles northeast of the city of Mt. Vernon.

GEOLOGY

The topographical features are not rugged, but graceful in outline and inclined to be symmetrical, due to glacial action. The debris of the glacial drift has been influential in forming contour and soil. Rock fragments occur abundantly, but nowhere are there giant boulders or distinct ledges of rock. The rock formations are composed of the Waverly sandstones and shales. The hills are a composition of shales, small boulders, gravel and sand. The subsoils in parts of the forest area are almost pure sand.

THE FOREST

There is standing today upon this tract one of the finest hardwood forests remaining in the United States. Composed of giant white oaks, chestnuts, bur oaks and sugar maples, with an under-wood of dogwood, blue beech, maple and iron-wood, it presents indeed a sight of its kind not to be duplicated within the limits of Ohio. Many individuals of the white and bur oak range in size from three to five feet in diameter, with a height of from 90 to 130 feet, having a clear length of 60 to 80 feet, and scaling as high as 3,000 board feet of lumber. The stand of original trees is not normal, but like most remnants of the virgin forest, many of the trees have fallen before the ax or storms. The open spaces thus created have come up in second growth oak, maple and chestnut.

The area has never been pastured, and the protective undergrowth has exerted a good influence in preventing the decline of the large trees.

PLANS FOR OPERATIONS

The possibilities in reconstruction, improvement and demonstration are so manifest that it appears to be a rare opportunity for the Station to undertake the task of establishing a demonstration and experimental area, and at the same time of holding intact and increasing the longevity of the splendid trees. From the nature of the forest growth regeneration must be largely by artificial means. The system to be followed must necessarily be that of the group or patch method. Considerable open space exists among the large trees, and in places the areas may be enlarged by the removal of weed trees.

A forest to be reconstructed by group plantings. The trees marked with the white square are to be removed and the space they occupied is to be planted to tulip poplar and black walnut.

It is intended to utilize commercial evergreens to a considerable xtent in the planting operations, These species not only possess alue as forest trees, but their presence in groups will produce an esthetic effect as well. Evergreens are particularly desirable, on ccount both of their supposed beneficial influence upon tubercular atients and of their adaptability to the soil conditions. It is ntended to established a pinetum, near the buildings, bringing into se every possible evergreen conifer. Plans for the operation of

the forest were made during the past summer, supplemented with a detailed topographic map, locating definite areas to be used for forestry purposes.

THE KENYON FOREST

The Kenyon forest, comprising about 200 acres, is located in Knox county about the village of Gambier.

It lies under the same geological influence as the Sanitorium tract, there being only four miles interval between the two tracts.

The forest is divided into seven parts, which are virtually considered woodlots. With the exception of two of the tracts, the forest is second growth. The first cutting was made over fifty years ago. The area surrounding the college buildings, and called "The Kenyon Hill Tract", contains a fine, virgin stand of oaks, with the white oak predominating. Unfavorable influences have played an important role in these woods. The term "woodland" could be more properly applied. The stand of original trees is under-normal and no young growth fills the intervening spaces, nor are there any factors favoring the perpetuation of the forest or the longevity of the existing growth. The ground cover and underbrush has for years been mowed and burned annually. Running fires have periodically swept the area clean of grass and debris, leaving the ground bare and exposed to the drying sun and winds. The younger trees were removed to present a park like appearance, and all regeneration, of whatever nature, has been persistently discouraged. How any of the large oaks have remained alive under such inimical influences is surprising, and careful observation makes manifest the need of the forester's services. Occasional dead, or partially dead trees, point to the inevitable result of destroying the natural forest conditions in virgin forests. Early decline and premature death may be expected.

The Harper, Bishop, Bixley and Academy tracts, consist of second growth timber. They have regenerated largely to black and scarlet oaks. Walnuts were planted in various places about the time of cutting, and have developed into good trees. The second growth white oaks are being eliminated by the more rapid growing black species, and decisive action is required to save them.

The Academy tract is a good example of the unpastured, second growth oak type of woodlot. The existence of a rank growth of dogwood, hickory and red maple reproduction, makes the area typical of the woodlots found throughout this region. The second growth stand is normal, but the reproduction is not suited to regenerate the tracts. Thus the solution of perpetuation must resolve itself into a change of the character of growth, by artificial planting and skillful silvicultural manipulation.

PLANS FOR THE RECONSTRUCTION OF THE FOREST

Two fundamental factors must be considered in the improvment of these tracts.

1st. The preservation of the primeval oaks that adorn the hills adjacent to the college campus. 2nd. Provision for the proper perpetuation of the forest. The latter is a matter of the greater importance.

In the "Kenyon Hill Tract" the stand is virgin with very little second growth. Unless provision is made for the establishment of young trees, ultimate decay will be inevitable, and a few years will find this area with few trees, and nothing in the place of those which have fallen. It is of vital concern that the start be made at once, in order to lessen the breach between the old and the new. Protection in the way of reproduction or undergrowth must be given the old trees in order to preserve them much longer. Hence, operations employed here have a dual purpose, and should be put into effect at once.

The group or patch system must be employed largely in reconstruction. The Kenyon Hill forest contains many open spaces, where no trees are growing, and openings may be created by the removal of defective or weed trees. These spaces, or plots, are to be planted to those species best adapted to general conditions. The plan is to employ a number of species, both coniferous and hardwood. Where occasion demands those species and sites best suited to improving the aesthetic condition will be chosen, but it is intended to group the plantings in such a manner as to obtain results both aesthetic and practical. The groups utilized in this system of planting may be extended from year to year, as may be required.

A clear cutting has been recommended for the "Flat Iron Forest". The growth is in such condition that it seems desirable to market the existing timber and to change entirely the character of the forest by planting, utilizing the few groups of natural reproduction established.

This region gives evidence of being well adapted to the coniferous evergreens. Splendid specimens of the white pine and Norway spruce are growing in and about the village of Gambier. The sandy nature of the soil on the Flat Iron tract makes it well adapted to pine, which should be used largely in the reforestation.

The various forest tracts of the College property will serve as demonstration areas owing to their similarity to the farm woodlots of that region.

Distorted white oaks which are injuring their neighbors. They are matured and should be removed.

THE OBERLIN MUNICIPAL FOREST

The municipality of Oberlin was the first to realize and take advantage of the benefits afforded the water supply by forest protection. The city has obtained possession of a 120-acre farm, through which the intake of the reservoir flows. The intake, which is a small creek, might be more properly called a large spring, as its flow is heavy and its seasonal variation is slight. Its course also is short, and does not extend to any distance outside of the municipal holdings.

The natural forest area of the holding consists of a 15-acre woodlot, the remainder of the land having been under tillage and in pasture. The intake was in no way protected from contamination or surface drainage from field or pasture.

Since arrangements for cooperation in reforesting the area have been made with the Experiment Station over forty thousand trees have been planted, and the work will be continued each year until the entire holding is reforested.

The soils are heavy, impervious clays, varying in places to a fine, compact, sandy soil. Lack of vegetable fiber, combined in places with poor drainage has been a discouraging feature in cropping the fields.

Catalpas and locusts were used to a considerable extent at the outset, but since, some of the native hardwoods have been utilized with encouraging results. The condition of soil and drainage will not permit the planting of a wide range of species. During the spring of 1910, 1,200 white pine and 500 black walnut and European sycamore were planted as an experiment. The white pines were placed upon high ground containing considerable sand. Thus far it seems that some of our native hardwoods are best suited to the tract. Reference may be made to the white ash in particular, the plantings of which are making splendid growth. The catalpas in part have done well. The soil in places has proved too wet for the locust, although on higher places its growth has been entirely satisfactory.

Several bushels of black walnuts were planted in the sod on the flood plain of the intake, but the germination percentage was unsatisfactory.

Group plantings were made in the native woodlot, which has been severely culled. Beech and ironwood have been removed in patches or plots and the areas planted. The ash and beech, however, have reproduced to such an extent, that in all probability further planting will be unnecessary. The woods, prior to a few years ago, had been heavily pastured. Within the past two years

A natural regeneration of shellbark hickory on the Oberlin Municipal Farm.

thousands of seedlings of ash, maple, basswood, etc. are noticeable. All ironwood and other prolific seed bearers and disseminators which are "weed trees" will be removed, so as to provide for regeneration with valuable species.

An interesting feature is the encroachment of the shell-bark hickory on the sod adjacent to the woodlot, where these trees cover several acres and are making rapid growth. They have been reinforced in places where the stand is too thin.

TRACT OF THE LIMA HOSPITAL FOR THE CRIMINAL INSANE

This area, consisting of 610 acres, is located two miles north of the city of Lima. The site, which has recently been acquired by the State, is an aggregation of several farms, and contains, in consequence, a number of woodlots. These areas are located in different parts of the tract, and are representatives of the typical farm woodlots of this region.

The growth consists of black, white, red, scarlet, bur and swamp oaks, sugar and red maple, beech, basswood (linden), white and red elm, black, white and black ash, shellbark, pignut and mockernut hickories. There are four woodlots in connection with the tract, three of which will be considered in the cooperative work.

PLANS FOR RECONSTRUCTION

South West Woodlot. This area is only a remnant of the original forest, and the trees that remain are in decidedly poor condition. It has been cleared of practically everything of value, and the remaining trees are culls. Many are dead at the top, and immediate action will be necessary to save the best from early decay. No reproduction nor protective under growth of any nature exists, and the ground in consequence is dry and hard.

The reconstruction process will be carried on by a system of group plantings, combining the placing and selection of species in a manner to produce both practical and aesthetic results, making provision for drives and vistas.

The Park Woodlot. This area lies adjacent to the building and is to be utilized for park purposes. It has been severely culled over during past years and practically all merchantable timber has been removed. Splendid specimens of beech, maple, elm and oaks still remain, with groups of iron-wood, blue beech and maple, which make it particularly adapted for park purposes. Trees for cutting have been marked, and roads and paths laid out.

Two regeneration plots of about one-fourth acre each have been reserved for the study of white ash reproduction.

Central Woodlot. This area lies adjacent to the park on the west. It has been heavily culled but never severely pastured, and in consequence contains considerable undergrowth. The white ash was at one time a prominent species. and these trees fortunately reseeded the woodlot before they were all removed. The reproduction of ash, in consequence, is a remarkable feature. This species forms at least 80 percent of the seedling trees, which are evenly distributed throughout the woods. Reproduction cuttings will be necessary from time to time, but no planting operations will be required.

Some experiments with direct seeding of ash have been planned and will be carried out the present winter or spring.

TRACT OF MIAMI UNIVERSITY

This tract includes about 35 acres of land, which is a part of the property of Miami University, located at Oxford, Ohio. The tract contains no woodlot, having been used for pasture purposes during the past years. The entire area will be reforested with different species of trees adapted to southwestern Ohio. It can be made an excellent experimental and demonstration area for this section of the state.

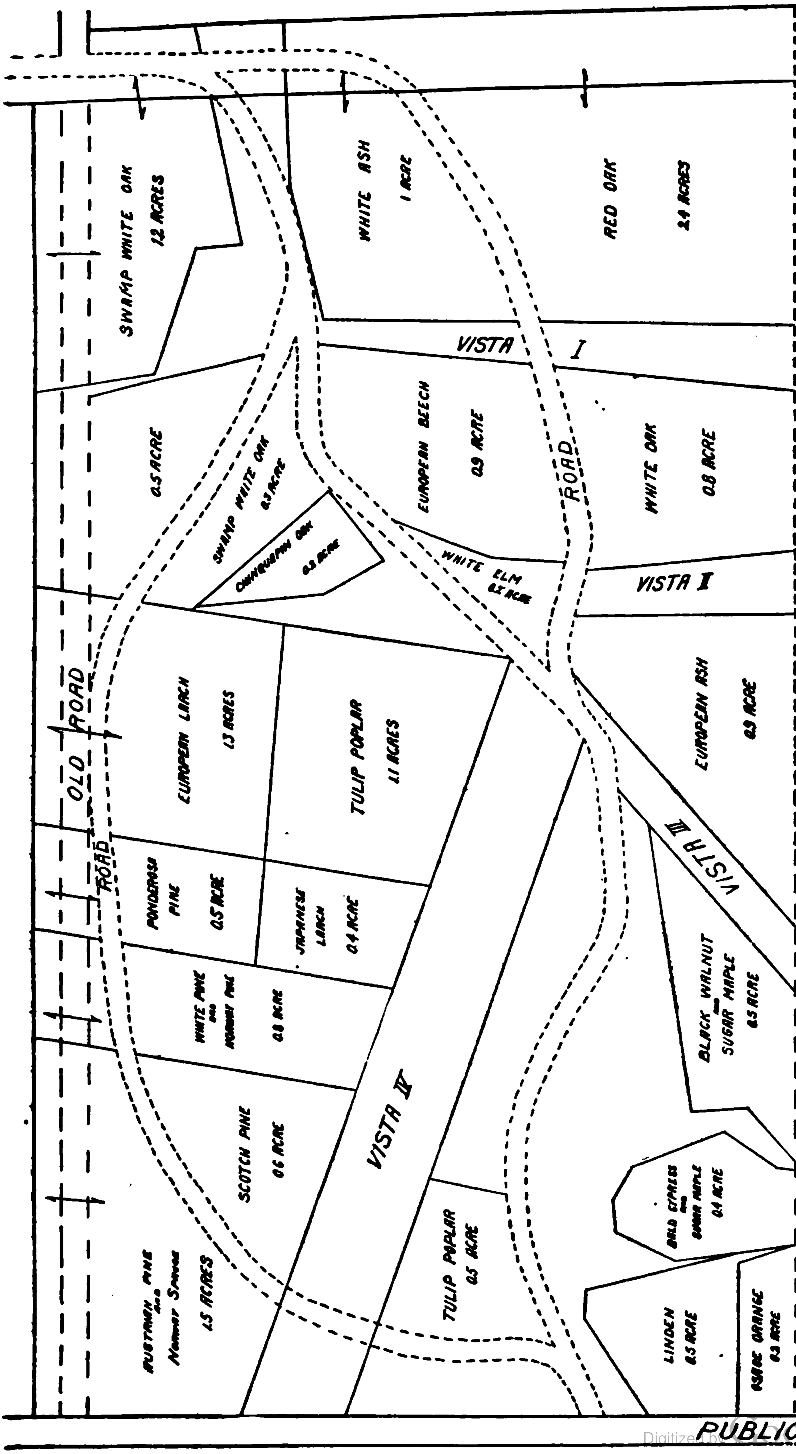
Operations were started in the spring of 1910, by an initial planting along the west border of the tract.

WORK AMONG PRIVATE OWNERS

Work among private owners has been along two lines, viz: The establishment of commercial tree plantations, and the reconstruction and care of the farm woodlot. This work was inaugurated in 1904, and although commenced in a limited way, and confined to the planting of post and pole timbers, it has grown steadily, and now includes the more extensive operations of reforestation along with woodlot work.

At the outset the information desired on forestry matters concerned only that with reference to the growing of post and pole timbers. Hence, this phase was taken up and encouragement given to land owners, by furnishing seedling trees to those who would plant and care for them according to the directions of the Station. Through this means the Station came in touch with the woodlot owners, and work in arousing interest in this important phase was begun.

The Station has always advised the reconstruction and care of the woodlot above all else. The methods employed in the improvement work, and the species of trees used, will vary with conditions.



Plan for the reconstruction of a woodlot on the tract of the State Hospital at Lima, Ohio

In all cases where planting was called for, those species best suited to the condition of soil and site and the needs of the owner were utilized. In many instances, if post timbers were needed, it was advised to plant trees adapted to this use in the open spaces in the woodlot, or those which could be made by the removal of either weed or matured trees.

Since the cooperative work has been inaugurated over a million trees have been distributed to land owners, for the establishment of experimental and demonstration plantations, and for the improvement of woodlots. This number includes practically all timber trees, whether native or exotic, which give promise of being suited to Ohio conditions.

ARTIFICIAL PLANTATIONS AND REFORESTATION

This work has encouraged the utilizing of waste areas about the farm in the better agricultural sections of the state, for tree planting, and the reforesting of waste bodies of hill land in parts of southern Ohio. The latter operation is distinctly different from the former. In agricultural districts, limitations must always be placed on the areas devoted to forestry, and the tree species must be those subservient to farm requirements. In other words commercial tree growing is of doubtful utility in certain sections.

In portions of southern Ohio there are thousands of acres absolutely non-productive, which cannot be reclaimed unless planted in trees. Under such conditions, as contrasted with the forestry problem in the good agricultural districts of the state, forestry plantations are a commercial venture.

In both cases, demonstration operations are under way, and various species of trees are being tested under different conditions of soil and site.

The utilization of barren areas is the greatest problem in reforestation. It not only entails the wise selection of species and mixtures adapted to soil and site, but it concerns itself with methods of procedure and with economic conditions, made complex by future contingencies. We cannot base our future needs upon what the present demands. Hence, the value of a forest just starting will depend entirely upon the demands for its product at maturity. Our economic conditions are constantly changing, and the demands made upon certain forest products at the present time may not exist fifty years hence. Handicapped by these limitations we will be safer in conforming to those tree species, whose products serve a variety of purposes, instead of those which have

limited utility. Rapidity of growth, adaptibility to conditions, and utility are the guiding features. Durability and a few other factors are important considerations, but they may be controlled largely by artificial means.

The problem of methods must be determined largely by experimentation. Briefly summarized, the following must be considered:

1. Adaptability to soil and site.
2. Distance of planting.
3. Adaptability of mixtures.
4. Thinning (stage and degree).
5. Rotation periods.
6. Harvesting.
7. Reproduction.

All of the above factors may vary under local conditions. The Station has inaugurated experiments toward a solution of these problems. Time will be required to obtain results in most cases, although some may be determined in a few years.

Enough is known about forest planting to proceed in a general way, but specific information regarding best methods is contingent upon first hand knowledge. It must not be assumed that forestry operations are impractical because of the lack of definite information, but the fact is, that a solution of best methods means increased profits from the operations. The European countries have persistenly increased the revenue of their forests through their past experience, and we can do the same under our conditions and much sooner than they, for we have the benefit of their experience.

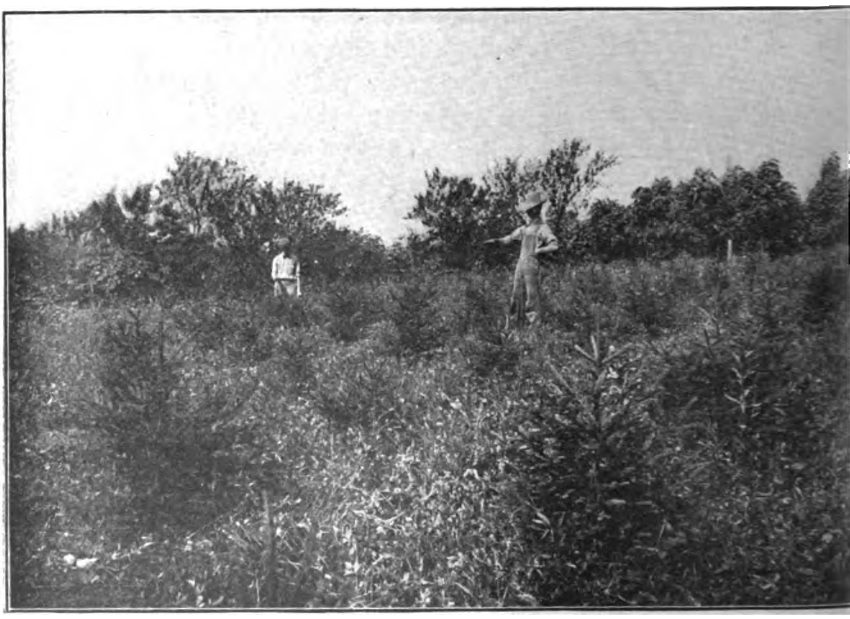
THE MANAGEMENT OF WOODLOTS AND FOREST TRACTS

Under this heading we are concerned with our native forests. The hardwood woodlot presents the most complex of forestry problems, but it does not necessarily follow that all woodlots are difficult to construct or manage profitably. Some of the problems are very simple indeed, but others are of such a nature that only the most carefully planned experiment will bring about a solution.

The comparatively high price of land in Ohio demands intensive methods of forestry. The methods employed in the management of remote mountain areas, far removed from market or transportation facilities, would not suffice in the Ohio woodlot.

To consider the problem rightly a general knowledge of woodlot conditions is desirable. The woodlots of this state are detached, irregular bodies of the original forest from which, in the great

majority of cases, the valuable merchantable trees have been removed, leaving those which were too small or were worthless for the market. Thus the stand is often not only under-normal but contains worthless trees. The removal of the latter class not only decreases the stand, but the remaining trees of merchantable species, if they exist, stand so far apart that they develop wide crowns and branching trunks, thereby destroying their value and preventing young trees from growing under them. It is frequently not desirable to make a clear cutting in a woodlot of this character, because of the doubtful utility of sacrificing the trees just mentioned on account of the growing value they possess. In woodlots where species exist which are usually reproduced by natural means, the the weed trees and matured trees may be removed gradually without opening up the forest at one time, allowing the young seedlings to fill the spaces, and thereby eliminating danger of making the opening too large.



A plantation of Norway spruce

It is unfortunate, however, that certain types of woodlots, containing under-normal stands, do not reproduce themselves to advantage. The young seedlings may be of weed growth.

The reproduction and second growth in many woodlots is worthless, and of such density that almost impenetrable thickets are formed. This frequently results where blue beech, iron-wood

and hickories occur. A woodlot of this character entails considerable expense in order to place it on a profitable basis, for it is necessary oftentimes to remove this growth with no sale for its products. Aside from this an outlay for planting is frequently necessary. It must be stated, however, that certain types of woodlots are most satisfactory and simple to operate. The ash, tulip poplar and maple types reproduce very readily if judgment and knowledge of silviculture are at hand. No phase of forestry may be said to be as practicable and profitable as the reconstruction of these woodlot types.

That the people of the state are becoming awakened to the practicabilitiy of wood lot operations, is evidenced by the constantly increasing number of applications for assistance in their management. The following table gives the percentage of applications received for the years 1904 to 1909 inclusive:

PERCENTAGE OF APPLICATIONS FOR TREES FOR GROVE PLANTING AND FOR WOODLOT IMPROVEMENT

	For groves Percent	For woodlots Percent
1904	100	0
1905	00	0
1906	94	6
1907	84	16
1908	70	30
1909	64	36
1910	59	41

The larger number of applications are filed during the winter months, and it may be expected that the number of applications for 1910 will be increased, and the percentage varied before the ending of the year.

A PLAN FOR THE TREATMENT OF THE WOODLOT OF EUGENE CRANZ

LOCATION AND AREA

The tract, consisting of 12 acres, is located in Bath township, Summit County, one half mile west of the village of Ira.

GEOLOGY

The woodlot is located upon the eastern exposure of the hills forming the western limits of the Cuyahoga River valley. The general slope varies from 2 to 10 percent. Two abrupt ravines, extending easterly, traverse the area on the north and south, forming an intermediate plateau, with a gentle easterly slope. The slopes of the south ravine are almost precipitious in places.

The soil consists of the clays of the glacial drift. They are light and of considerable fertility. The subsoil is inclined to be permeable and allows of good root drainage.

PRESENT CONDITIONS

The woodlot is a detached remnant of the original forest. A number of large trees have been removed, but the process of culling has never been carried far. The growth consists of beech, white ash, sugar and red maples, white and red oaks, tulip poplar, dogwood, iron-wood, black walnut, sour gum, black cherry, butternut, red elm, chestnut, hickory, and large-toothed poplar.

Previous to three or four years ago the area was quite heavil pastured. After livestock was excluded seedlings of practically all species present began to spring up, until at the present time reproduction of certain species extends over the entire area, with the exception of those portions too heavily shaded by mature beech and maple. The seed trees of ash, tulip poplar and chestnut are quite well distributed over the plateau between the ravines.

The immediate slopes of the south ravine are occupied by a stand composed largely of beech. Iron-wood seed trees have unfortunately been present, and in consequence the reproduction is composed quite largely of that species and sugar maple, both of which tolerate the heavy shade of the beech crowns.

Reproduction. White ash forms the largest percentage of reproduction. Tulip poplar, sugar maple, cherry and the oak seedlings are also abundant. The ash and tulip poplar are to be relied upon chiefly in composing the future crop. Chestnut, while of considerable importance, does not occur in sufficient quantity to influence the reproduction. The white oak is of slow growth, and not as adaptable to conditions as the other species. The red oak is well adapted to the site, but its reproduction rarely occurs. Reproduction in places is hindered by the shade of the overwood. In some cases weed trees, like beech, dogwood and iron-wood are overtopping and seriously injuring young seedlings.

The portion of the woodlot north of the north ravine contains a sapling stand of tulip poplar, red oak, beech, mulberry, white ash, hickory, black cherry, butternut, black walnut, sugar maple, red maple, and large-toothed poplar. This growth has resulted from a clear cutting made about twelve or fifteen years ago. The valuable trees in this growth do not form over 25 percent of the stand.

PLANS FOR IMPROVEMENT

One of the first principles of agriculture is that every acre of ground should produce all that it is capable of producing. This principle applies equally well to the woodlot. In order that a woodlot may be worth holding for such purposes it must contain some young growth of value.

The possibilities in reconstruction are greater in this woodlot than in the majority of its particular type. The important factor, which makes reconstruction comparatively easy, is the readiness with which natural reproduction took place as soon as conditions were made favorable for its existence.

Cuttings. This woodlot could in all probability be entirely reconstructed by natural regeneration, although in certain specific cases planting would probably be more profitable. The system of reproduction cuttings under the patch or group method of thinnings can be most successfully applied. Cuttings made with the idea of establishing a new growth of trees, in place of those removed, may be called reproduction cuttings. Under the patch method, plots of worthless or matured trees are removed and the area allowed to regenerate to a new crop, or is planted to species desired. Other systems of management might apply here, but the conditions influencing this particular case seem to warrant the above method being used.

A profitable walnut grove in Wyandot county

Areas varying in size will be selected, and the large or weed trees removed. These areas will contain largely beech, dogwood, ironwood, etc. This same method will apply where the poplar and ash trees are desired for building purposes. While the group plan may be adhered to as the general principle of regeneration, cuttings of

individual trees must be made where worthless trees overtop groups of seedlings. The removal of seed trees of undesirable species, as iron-wood, blue beech, beech and red maple, all of which are prolific seed bearers and disseminators, is necessary. Moreover, they have a marked degree of shade endurance, and are prone to establish themselves under cover of the older trees, where much of the desirable reproduction will not exist. Such has been the case on the area where the clear cutting was made, the stand here is composed of 75 percent weed trees.

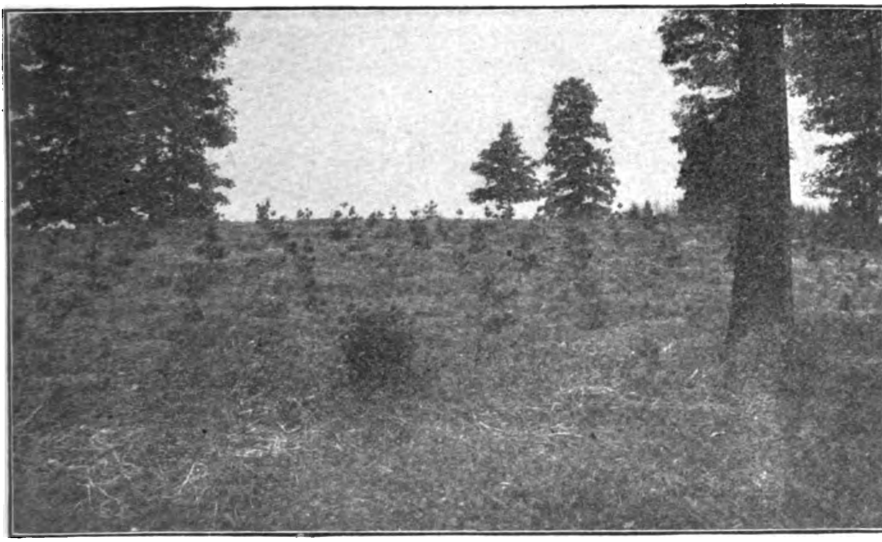
Planting. The operation of planting, while many times necessary in woodlots, is often misused, and trees and labor are wasted. For profitable reconstruction in parts of this area, however, planting of trees will be required.

A portion of the southern exposure of the south ravine (area P), consisting almost entirely of beech, was clear cut during the winter of 1909-10 and planted to white pine at a distance of 6x6 feet. This species seems adaptable, owing to the comparatively thin soil and southern exposure. The beech in this case was utilized for firewood. It is recommended that the entire southern exposure of the ravine be clear cut of the trees now growing, and be replanted to white pine as far as the degree of slope permits. The pine should be planted in mixture with Norway spruce or European larch. Clear cutting is also recommended for the northern exposure. Some reproduction of iron-wood and sugar maple occurs here. Tulip poplar and red oak should be interplanted; chestnut may also be used, the spacing being about 6x6 feet. All planting should be done the spring following the removal of the timber, and the area cleared each year should not be greater than can be planted each spring. This will serve to check the deterioration of the soil by exposure to drying and washing and the subsequent loss of vegetable fibre. A season's growth of stump sprouts, grass, etc. which invariably spring up with the removal of the large trees, may seriously interfere with planting operations. This condition is one of the worst difficulties attending planting operations on cutover land.

Open spaces (R) have existed for a number of years and the reproduction in consequence has attained better development. In the spring of 1908 some catalpas were interplanted among the ash, tulip, cherry, oak and iron-wood seedlings. They have done remarkably well.

The cutover area (S) should receive early attention. The weed trees should be cut out and the tulip poplar, ash, oak and walnut saplings, forming about 25 percent of the stand, should be reinforced with white pine and Norway spruce. Larch and bald cypress may be used in the more open places.

The area (Br.) consists of a growth of weeds and briars. They may be cut with a brush hook. A planting of red oak and red maple in mixture is recommended. The species may be planted alternately six feet each way.



A plantation of white pine at Wooster

Logging Operations. These operations do not call for any amount of skill, although the process of removing the logs from the south side of the south ravine is a difficult one. This may be accomplished by precipitating the logs into the ravine and following its course to the mouth.

Favorable Influences. The favorable influences must always be considered in woodlot reconstruction. The reservation of the area from live stock is the paramount consideration. Before attempting operations, one must thoroughly make up his mind that no animals shall be allowed to browse within the woodlot limits. Possible exception may be made in the case of hogs. Factors which provide for and maintain good forest conditions must be thoroughly understood. It is a matter of considerable importance that the leaf litter be preserved to form the necessary mulch for the trees, and to maintain and increase the fertility of the soil. Care and judgment should be exercised in felling trees and removing timber, so as to afford as much protection as possible to the young growth. For this purpose spring cutting is not advisable. At this period all

growth is succulent and very susceptible to injury. The prevention of fires, which might follow negligence in burning brush is essential. A fire may destroy, in a few hour's time, what may have been accomplished in as many years. The careful selection of seed trees of the right species, and the removal of those which are weeds is to be attended to. Matured or weed trees, which interfere with the development of the valuable reproduction should be removed. The foregoing are all important factors, which go to increase the productiveness of forest land.

Wind Break. The establishment of a dense growth about the borders of the woodlot is of considerable importance. This prevents the wind from blowing the leaves away, and thereby prevents the encroachment of grass which is inimical to tree growth. It also prevents windfalls and injury to the trees within. Evergreens are the most satisfactory for this purpose, owing to the manner in which they retain their lower branches. Two rows have been planted along the west border of the woodlot, and a similar planting may be made on the north side. A portion of the west and south sides are protected by adjacent woodlots. The east side is protected on account of being at the base of the slope. The pines on the west are planted alternately 6x6 feet.

Summary of Recommendations. 1. The entire woodlot, as far as practicable, should be reconstructed by the reproduction of the original valuable species it contains, reconstruction to be carried out under the patch or group method by reproduction cuttings.

2. Groups of the most worthless trees to be first removed.

3. Clear cutting to be made of beech, maple and oak on both slopes of the south ravine.

4. All prolific seed bearers, disseminators of weed species, to be removed. This includes iron-wood, blue beech, and in some cases red maple.

5. All weed or matured trees overtopping young seedlings to be removed.

6. In the regeneration of the woodlot, tulip poplar, white ash, chestnut and red oak should be favored.

7. The weed trees to be removed from the cutover area (S).

8. The south slope of the ravine to be planted to pine and spruce. Trees to be spaced 6x6 feet.

9. The north slope to be planted to hardwoods, tulip poplar, chestnut, and red oak, spacing 6x6 feet. All planting to be performed the spring following the removal of the present growth.

10. The 25 percent stand of merchantable saplings on the cutover area (S) to be reinforced with white pine and Norway spruce, the former in the more open spaces, and the latter in the shaded

portions. Bald cypress and European larch may be used sparingly in open places.

11. Area (Br), containing briars and weeds to be planted to red oak and red maple, spaced alternately 6x6 feet.

12. A wind break of white pine to be maintained along the exposed portions of the west border of the woodlot.

13. The leaf mulch to be carefully maintained.

14. No cuttings to be made during the months of March, April and May.

15. Protection to be given against fire, bearing in mind that a fire may in a very short time seriously injure the young trees and eventually kill all.

16. *The absolute exclusion of all livestock from all parts of the woodlot.*

THE FOREST SURVEY

This work was begun in 1906 in a limited way and has been carried on each succeeding year, so far as consistent with available funds.

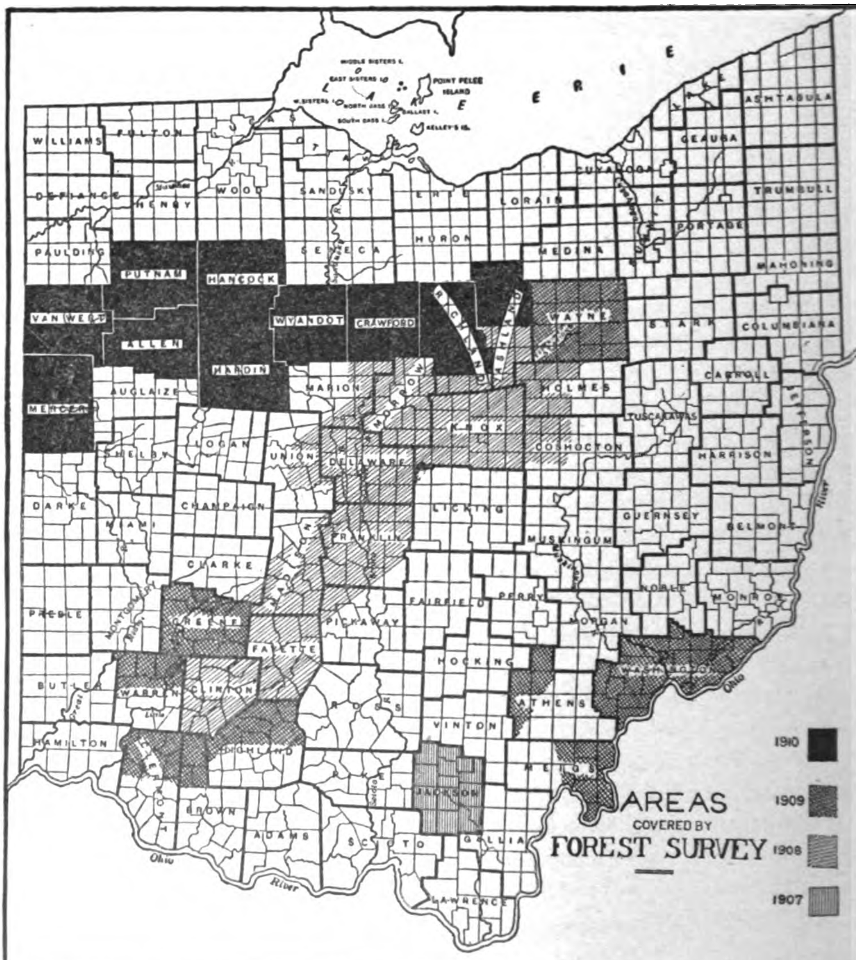
During the summer of 1910 two men were employed. The area covered includes ten counties, viz: Ashland, Richland, Crawford, Wyandot, Hardin, Allen, Hancock, Putnam, Van Wert and Mercer. The survey was only preliminary and in the nature of a reconnaissance. The chief work consisted of the inspection of the artificial tree plantations, established in cooperation with the Station. Data were taken on many of the groves under different conditions of soil, site, and systems of treatment, and suggestions were given for their future care. Many other plantations, established independently of the Station, were examined and data obtained. Parties applying to the Station for assistance in the different phases of forestry work were seen, and suggestions offered to meet their particular needs.

Another important phase of the survey consisted in the examination of the native woodlots. The various types throughout the region traversed were studied, and data taken on their condition.

RESULTS OF THE SURVEY

Succinctly stated, the information obtained through the survey indicates that practically no knowledge of fundamental forestry principles exists among land owners. In many cases where the initiative is assumed by an interested woodlot owner in an attempt to improve his woodlot, the methods employed have been precisely the reverse of proper procedure. No operations in agriculture require more skill and basic knowledge than those which underlie

forestry. In the operations of the field, where annual crops are produced, errors in management may be rectified from year to year. In those of the forest, where many years are required to produce the crop, there are no possibilities of correcting errors, excepting through great loss. Hence, the value of well laid plans in accordance with well known forest principles cannot be over-rated. Education,



therefore, must necessarily be an important factor in influencing progress and the knowledge disseminated should come through technically trained men, who can study the problems understandingly, and whose solutions are aided by, and based upon, previous training, coupled with experience and knowledge of conditions. General information will not suffice. Individual conditions and problems must be studied and met, and specific remedies applied.

A woodlot to woodlot canvas is the very best solution of the problem of education, as well as for determining conditions and specific needs. Woodlots are individual and the treatment prescribed for one, in all probability, will not apply exactly to any other.

A forest survey offers the only opportunity of becoming familiar with the forest conditions of the state, and upon these conditions must be based the entire forest policy. The survey stands for organized research, and is the determining factor in experimental forestry. It is the most useful means of setting forth the aims of forestry, and in determining where it can best be practiced. Results of a crusade of this nature, as far as the education of the public is concerned, are not always apparent, and may be discouraging or seemingly lacking. It is a virtual impossibility, under the limitations of our knowledge of silviculture, to answer all the questions of the public, and it is impossible to induce many to attempt operations. It is a new venture, and there is a just hesitancy to undertake work in an unkown field. The time limit and lack of object lessons are futher barriers. However, the approach of the forester and a few simple explanations of how the woodlot might be made more productive, the setting forth of the value of growing timber or the imprudence of cutting young trees from steep hillsides for the sake of a half crop of tobacco or corn fodder, all has its influence. It starts the land owner to thinking, and although he does not always commence active operations to plant his untillable land, or improve his woodlot, he concludes to let the timber remain that he previously intended to cut off. Without doubt thousands of dollars have been saved to the land owners of Ohio through eight or nine months of the forest survey. Many thousand feet of lumber will be marketed which was unconsciously being allowed to deteriorate in the woods. Millions of young trees have been saved from the browsing of livestock, and will be delivered as a heritage to future generations, being valued meanwhile as a growing asset to the land on which they stand. Many suggestions have been put into practice and become object lessons for others to follow. Many steep, eroded hillsides will be clothed in the garments that rightfully belong to them, although the crusader may never know that the awakening was the result of his work.

TREE PLANTATIONS

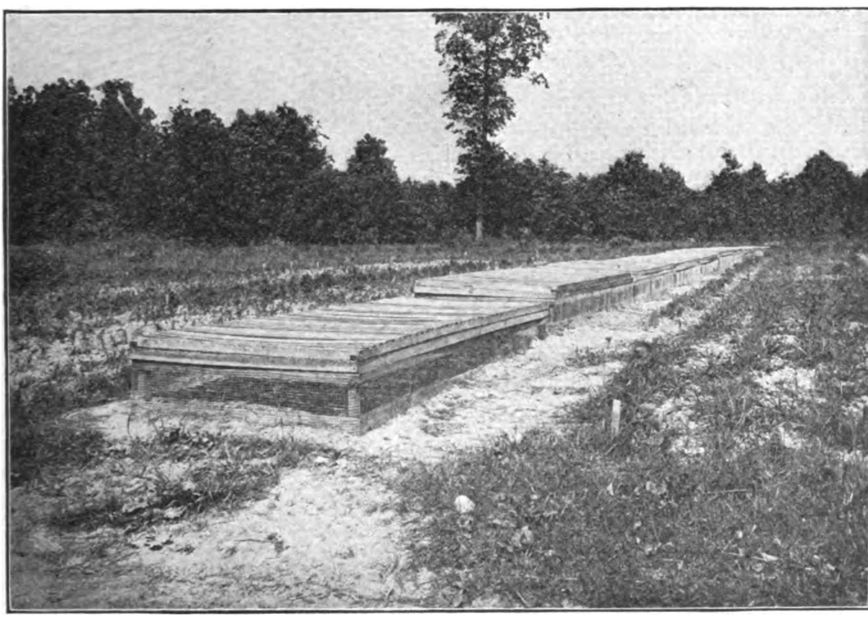
There has been considerable interest manifested in the planting of groves for post and pole materials and windbreaks. The greater number of these groves are catalpa. This species has been popular with the farmers in the better agricultural districts. The groves examined have done fairly well. Neglect has been the worst diffi-

culty with which to contend. A catalpa or locust grove can be neglected and still survive, while a corn field cannot. In other words, many of these groves are neglected on account of the necessity of attending to other farm crops.

Cultivation. Cultivation is one of the most important features, where plantations are established on tillable land, and it is one that is the most neglected. Tree growing in good agricultural soil requires the very best of treatment to produce reasonable profits. The tendency among owners is to cultivate for the first or even second year, frequently growing crops between the trees. The effect of this treatment is manifest for the first three years, but thereafter comes a slump in development. Groves in which judicious cultivation was carried on for three or even four seasons have shown results from such treatment. Grass and weeds are the worst enemies resulting from lack of cultivation. Where trees are spaced eight or ten feet apart the widest way, cultivation can be very conveniently carried on for three years. Three cultivations per season under ordinary conditions will suffice. It is usually better to grow crops for the first two seasons. Soybeans, cowpeas or possibly buckwheat, are good crops to sow with the cessation of cultivation, and even during the period of cultivation. These crops may be allowed to fall and serve as a mulch. It seems especially important that a cover crop be sowed after the last cultivation. Deep cultivation the third season may do considerable injury, by destroying the fibrous roots lying near the surface. This is particularly true when culture is neglected the first year or two. This same principle may apply the second season, providing no tillage is carried on the first. In order to get the best results, therefore, it is important that cultivation be started as soon as necessary after the setting of the trees, and continued faithfully until the close of the third season. Exception should be made in case of non-tillable land or slopes or flood plains liable to wash.

Mulching. Mulching is one of the most practicable forms of culture where trees are planted on slopes and hillsides liable to erode, and upon non-agricultural land. It is also of good utility after the cessation of cultivation, particularly on heavy soil liable to pack or bake, and in that devoid of vegetable fibre. The straw of many field crops, also tree leaves, may be used for mulch material. Wheat straw is the most easily obtained and probably the most economical. An application may be made four or five inches thick within a radius of three or four feet about the tree. In cases where cultivation has been neglected the grass and weeds may be cut and placed about the trees.

That mulching increases liability of mice injury is true, although by proper management this difficulty can be eliminated. It has been observed that ordinarily mice do not like to work far from cover, and their ravages are always worse where dead grass or debris of any kind is lying adjacent or close to the tree. Little injury has been observed where the ground is bare close about the trees, unless there has been a covering of snow, under which cover mice sometimes work. As a means of preventing injury, therefore, it is advised that all mulch material be drawn from each tree within a radius of at least two feet, and all grass or debris of any kind should be ncluded, leaving the ground as bare as possible. These precautions may be supplemented by throwing a shovelful or two of dirt about those trees liable to injury.

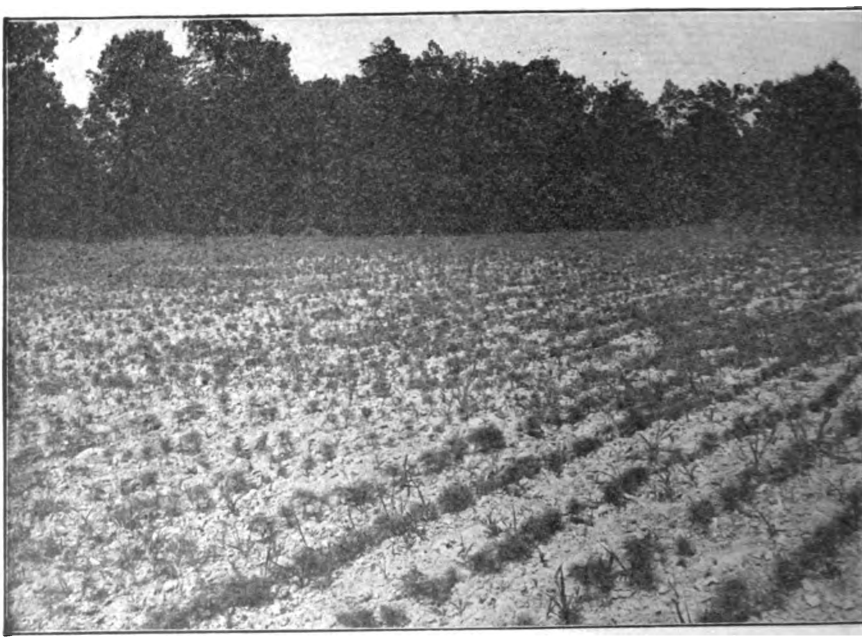


Beds for propagating evergreens

Pruning. With certain forest trees pruning operations are second only to cultivation in importance, and often second to none. This operation is of special importance in growing the catalpa, which does not prune itself of side branches. Almost all species used in commercial plantations may be pruned to greater or less extent with profit.

Observations of the survey indicate generally a seeming lack of knowledge in regard to the proper methods and function of pruning. Where such operations have been undertaken in a grove they are

usually carried to the extreme, or are conducted in such a manner as to fail to accomplish the purpose for which pruning is intended. There is a lack of knowledge among many regarding the function performed by different parts of the tree, and in consequence pruning cannot be carried on intelligently. The branch of a tree is generally considered a necessary evil, and a thing to be gotten rid of in order to produce timber. It is of course necessary to prune, but it is important to know what limbs to remove and to what extent such operations should be carried. Judging from experience of the past, it is evident that instruction in the principles of pruning is a matter necessitating actual example on the ground. Suggestions given through the medium of bulletins, along with illustrations, serve to give considerable information, but results are not as satisfactory as those obtained through actual demonstration.



One-year-old white pine transplants

A detailed discussion of culture and pruning will appear in a separate publication of this Station.

Nursery Stock. Too much care cannot be exercised in securing good nursery stock, and in the case of catalpa, that which is true to name. There has been frequent misrepresentation by unscrupulous and uninformed persons, who traverse the country represent-

ing themselves as the agents of nursery firms. In many cases these individuals do represent firms of unknown reputation; in others the firms they claim to represent do not exist, but inferior stock is bought and delivered to parties to fill orders taken. Cases of misrepresentation are confined largely to the catalpa, but other species are also involved. The grossest misrepresentations regarding the true status of catalpa have been made, and have induced parties to purchase stock of unknown origin, at exorbitant prices. Cases are known where from twenty-five to forty dollars per thousand has been paid for 12- to 18-inch catalpa and locust seedlings, with the advice that they be planted at the rate of from 2,000 to 5,000 per acre, supplementing this with the startling information that they grow to post size in three years, and pole size in six to ten years. These statements are so grossly exaggerated that they should appear manifestly untrue to even the most uninformed. Not only does such action operate against the land owner and the cause of forestry, but it is a hindrance to the welfare of honest nurserymen, and has caused some to discontinue handling the catalpa. It is as much to the interests of the forest nurserymen to cooperate in stamping out this practice as to any concerned.

THE SPECIES OF CATALPA

That there are several species of the catalpa, only one of which is suitable for forestry planting, is not as well known as it should be. Prior to this time, cause existed for the distribution and planting of the wrong species, but with the dissemination of information, through our agricultural institutions and press regarding this matter, there is no excuse for the prospective planter being uninformed and much less for the party who sells and distributes the seed and trees.

Throughout the area covered by the Survey the number of groves containing spurious trees is startling. Spurious stock has not only been distributed during the past, but what is worse, is still being sold.

The species of catalpa cannot usually be determined until the tree has made several years' growth. It is very difficult if not practically impossible to determine species of seedling trees, especially when the leaves are off. The loss attendant upon planting the wrong species is two-fold, owing to the non-productivity of the land from the time of setting the seedlings until their true nature is evidenced, and to the outlay involved in planting and care. It is evident, in the light of facts obtained by the Survey, that too much care cannot be exercised in securing catalpa speciosa seed and trees true to name.

Prices of Forest Tree Seedlings. It is impossible to give definite prices on forest tree seedlings, as such will vary with many conditions. Prices on catalpa and black locust seedlings for the season of 1910 have been secured from ten nursery firms. These figures are based on 18- to 24-inch seedlings:

PRICES OF TREE SEEDLINGS

	Average Price	Minimum Price	Maximum Price
Catalpa	$5.98	$3.00	$11.00 (delivered)
Locust	$5.80	$3.00	$ 8.75

Catalpa seedlings in nursery

WOODLOTS

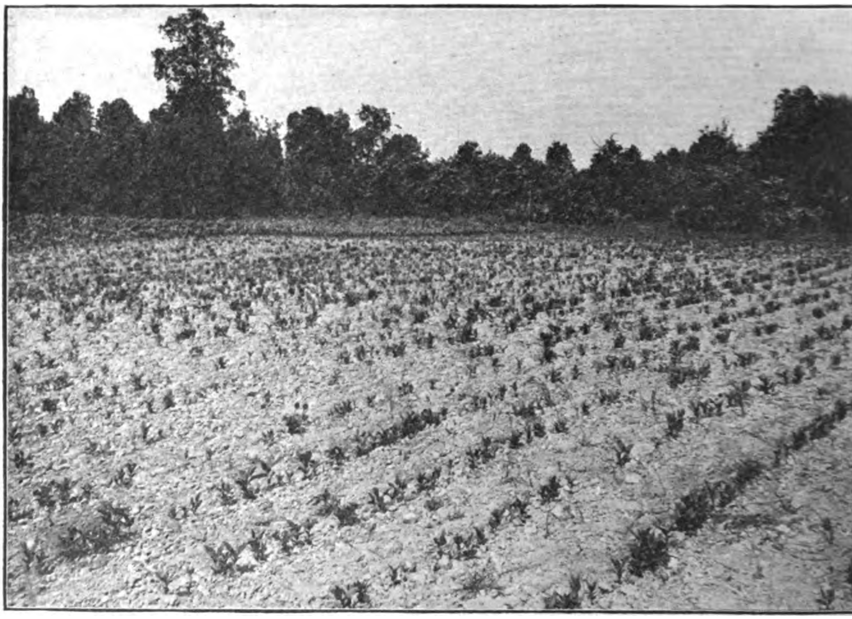
In the forestry operations of Ohio, the farm woodlots have always been considered the paramount factor, and work in their reconstruction and management has been encouraged as much as possible. A portion of the area covered by the Survey contained a large number of these tracts, the average size of which is about fifteen acres. It was impossible to examine every woodlot, but a study was made of the more typical examples. Indications point to a slow but evident awakening to the importance of these areas, and a disposition among owners to study and improve their condition. One of the problems to be solved is that of directing energy in the

proper channel. Among those who have undertaken the task of improvement, many have chosen the wrong course at the outset. One of the most common errors attributed to woodlot owners is their attitude toward undergrowth and reproduction. Almost invariably undergrowth is considered a detriment, and one of the first factors to be eliminated. The only asset considered is the large trees. The small ones which are growing into value, besides serving as a protection to the older ones, are destroyed as weeds. It is frequently found that sheep and other live stock have been turned into the woodlot for the purpose of cleaning up this growth, little realizing that the fundamental principles of forestry were being violated. In other cases the expensive operation of cutting out the undergrowth was being practiced. Examples of removing young, valuable poplars, oaks and ash for the purpose of planting exotic trees for certain special purposes are frequent. There is a general disposition to preserve mature trees, even though they are on the decline, and should be marketed. The idea of the utility of natural reproduction in perpetuating the woodlot is seldom conceived, nor does it seem to be popular when advanced. The prevailing opinion is the necessity of planting, instead of allowing the woodlot to reseed itself in so far as practicable, and aiding this by skillful manipulation of the axe in removing undesirable trees; not realizing that in improvement operations the axe must play as important a role as the spade.

The pernicious habit of grazing woodlots is the most disastrous influence tending to destroy the forests of Ohio. Unlike the ravages of fire, it is insidious in its nature, and is not commonly observed until the evil is accomplished, and even then the injury is not apparent to many. Before attempting to describe the evils resulting from this practice, it seems advisable to set forth some of the principles underlying woodlot operations, which are violated by grazing. One of the first requirements of a profitable forest is that it contain young trees. This protective undergrowth is beneficial in shading the ground, preserves the moisture, adds humus and vegetable fibre to the soil, and prevents the growth of grass, which is harmful to trees.

Grazing destroys all these factors and works further injury by puddling the soil and exposing the roots. Animals maim the latter by trampling. Browsing not only destroys young trees but often distorts them in such a manner that they never develop into merchantable trees. Before attempting to improve a woodlot one must resolve to exclude livestock, and remain firm in the resolution.

The loss entailed through the practice of pasturing is enormous. While there are no definite estimates of the damage in money value, it may be conservatively said, that it amounts to many thousands of dollars.



White ash seedlings one year old

The great majority of existing forest tracts are not real woodlots but mere woodland pastures, having no real value for forestry purposes and but little for pasture. The trees they contain are not sufficient in number nor kind to make them of any value as timber tracts, and yet there is too much shade to allow a stand of nourishing grass to grow. In many cases, therefore, these woodlands are being sustained at a loss to the owners. The actual value of the woodland pastures, as estimated by 2,365 owners, does not exceed 15 cents per acre annually, and the value of the stand of trees is worth little, because those which remain have been damaged by browsing. Frequently the loss is two-fold by allowing the matured trees to deteriorate instead of marketing them. It is often evident that trees in a woodlot are not looked upon as a crop. The fact that they grow and mature as any other crop is not realized by the great majority of people. The popular idea of a woodlot seems to be only in terms of large trees, which are looked upon as remaining indefinitely, unless destroyed by the axe or the hand of Providence. To many, a young tree is nothing but a weed.

Statistics place the number of acres of forest land in Ohio at 2,275,069, which is 13 percent of the total area. The investigations of the Survey show, as far as its limits extend, that 85 percent of the so called forest areas are not real forests, but mere woodland pastures and worth but little for pasture purposes.

The following table shows the number of woodlots examined:

A indicates the precentage of areas which have no value for forestry purposes, and which cannot be profitably reconstructed.

B, those which are pastured, but by the exclusion of live stock can be reconstructed.

C, those areas which have not been pastured.

The data includes the territory covered by the Survey during the season of 1910.

RECORD OF WOODLOT SURVEY IN TEN COUNTIES, 1910

County	Total number woodlots examined	Pastured A	Pastured B	Un-pastured C	Percent pastured A	Percent pastured B	Percent Un-pastured C
Van Wert........	168	91.	56.	21.	54.0	33.0	13.0
Richland	291	120.	96.	75.	41.5	33.0	25.5
Mercer...........	225	100.	101.	24.	44.4	44.9	10.7
Wyandot........	199	116.	54.	29.	58.3	27.1	14.6
Hardin...........	265	145.	88.	32.	54.6	33.2	12.2
Putnam..........	267	122.	106.	39.	45.5	40.0	14.5
Ashland.........	120	55.	43.	22.	45.8	35.9	18.3
Crawford........	232	123.	70.	39.	53.0	30.2	16.8
Allen.............	225	128.	70.	27.	57.0	31.0	12.0
Hancock.........	373	199.	114.	60.	52.0	31.0	17.0
Average.........	....	119.9	79.8	36.8	50.61	33.93	15.46
Total............	2365	.....	.....	....	.....	....	.....

The problem of forest and pasture can be solved in many cases by dividing the woodland into two parts, reserving from livestock the portion best suited to forestry purposes, and devoting the other portion to pasturage, clearing off all the trees excepting those desired for shade.

FOREST NURSERIES

The Station has several acres devoted to the growing of forest and ornamental tree seedlings. Nurseries have been established in connection with the Experiment Station at Wooster, the Boys' Industrial School at Lancaster, Kenyon College at Gambier, the Sanitorium at Mt. Vernon, Miami University at Oxford, and the Lima State Hospital at Lima. This work is being carried on in a

limited way at the institutions, but it is hoped to enlarge the areas and increase the number of trees grown each year. A variety of species is being grown at each place, and good results will be obtained with regard to the adaptability of different species to soil conditions.

A fine line of exotic ornamentals is growing in the Wooster nursery. This number includes a collection of many rare and beautiful trees. 169 species of trees were planted in the spring of 1909 and of the entire number only one species entirely succumbed to the unusually severe winter conditions.

The following is a list of the more important forest tree seedlings in the Station nurseries.

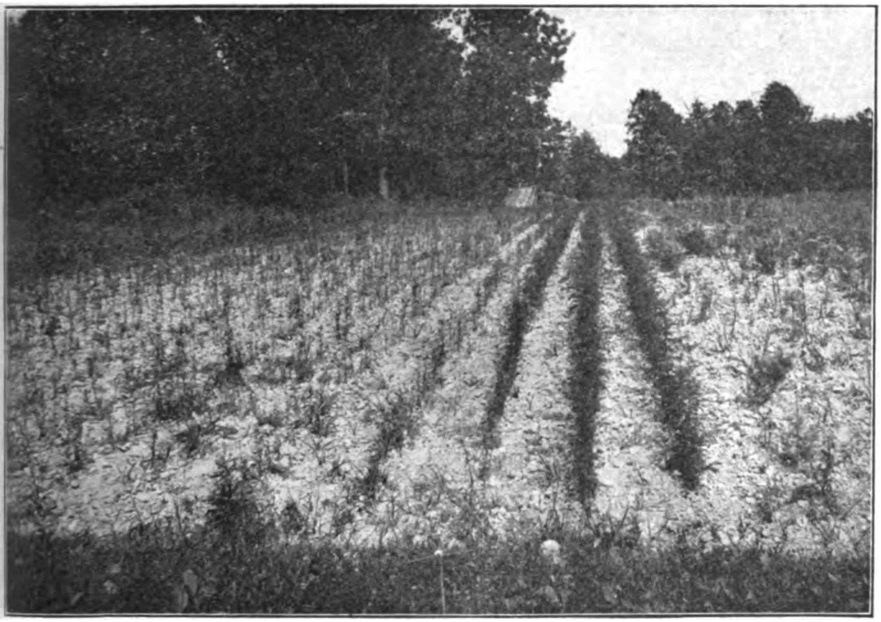
Species	Size		Number
Ash, European	18 to 24 inches		600
Ash, White	6 to 24 "		69,000
Catalpa	6 to 24 "		273,750
Cypress, Bald	12 to 24 "		3,575
Larch, European	10 to 18 "		4,635
Hemlock	6 to 12 "		5,100
Oak, Burr	12 to 24 "		930
Oak, Red	6 to 12 "		8,000
Pine, White	3 yrs. trans.		28,500
" "	2 yrs. trans.		45,380
" "	3 yr. seedlings		4,000
" "	2 yr. seedlings		6,000
" "	1 yr. seedlings		100,000
Pine, Norway	12 to 18 inches	trans.	450
Pine, Austrian	6 to 8 "	"	1,400
Pine, Scotch	6 to 8 "	"	1,150
Pine, Banksian (Jack)	6 to 8 "	"	2,000
Poplar, Norway	18 to 24 "	"	550
Spruce, Norway	10 to 24 "	trans.	6,800
Walnut, Black	18 to 24 "		500
Spruce, Douglas	6 to 18 "	trans.	1,350

Practically all these give evidence of adaptability to soil conditions, notwithstanding the unfavorable season of 1910. The white pine is a particularly promising tree, and will no doubt be of great utility in the reforesting operations of southern Ohio. It has shown a special fitness for Wooster and Mt. Vernon soils.

There is need of larger areas and better facilities for the work. The present capacity of the nurseries is over half a million trees, but this should be increased to at least twice the amount. It is important also that a system of water supply be provided. Such system could be used to advantage every season.

FOREST TREE DISTRIBUTION

The station has distributed seedling trees gratis since 1904. This distribution has been entirely for demonstration and experimental purposes. It appeared to be an excellent means also of encouraging forestry sentiment. Enough groves of certain species have been established in many sections of the state to serve the purpose for which they were intended. Distribution in these particular sections will cease. Exceptions will be made, however, in cases where trees are required for the solution of peculiar problems.



Bald cypress and European ash in nursery

It is unfortunate, in the case of catalpa, that difficulty has been experienced in securing the speciosa true to name. This feature has led the Station to continue the distribution of this species to a greater extent than it otherwise would have been justified in doing. Information in regard to the real nature of this tree, however, has been so disseminated among commercial growers, that it is now possible to obtain it with considerable assurance of its purity, and at reasonable prices. It is hoped, therefore, that commercial nurserymen may relieve the Station of this feature, excepting, as before mentioned, in cases where experimental and demonstration operations of a peculiar nature are required.

OPPORTUNITIES FOR FOREST NURSERYMEN

The present agitation in favor of forestry and the consequent demand for forest seedlings has opened a market of no mean proportions. It is hoped that Ohio nurserymen may devote areas to the growing of these seedlings in connection with their general nursery stock. This work should be placed upon a commercial basis in order that the stock may be disposed of at minimum prices, thereby offering inducements to land owners to buy. The prices of evergreens suitable for forest planting are prohibitive, due to no fault af the grower, but to the fact that the trees are grown to supply retailers who dispose of them in limited quantities for ornamental and wind-break purposes. These trees are better grown than are required for forestry purposes. The Station wishes to encourage those who are inclined to these phases of commercial growing.

DESTRUCTIVE AGENCIES

Forest Fires. Fire annually burns over thousands of acres of forest in different sections of the state. The Ohio river counties suffer most damage in this respect. The causes are attributed to different sources. Railroads are responsible for the greater number of fires. Where the right of way passes through or adjacent to forest tracts, the stubs of dead trees and inferior coppice growth gives evidence of the damage done. Carelessness in burning brush and stubble land, and allowing fire to escape, has been the source of many fires. Campers, hunters, and smokers have also contributed to this evil.

Injury to woodland by fire does not seem to be generally recognized nor fully appreciated. Of the numerous ways in which fire may be injurious, only a few are realized. Damage to a forest is always apparent when the large trees are killed outright or badly fire scarred, but one of the greatest evils, that of the destruction of young growth, is rarely noted as being of any consequence. The same principles are involved in this case as in the practice of grazing woodlots, but the injury by fire is many times worse, and works with greater rapidity and devastation. Not only are all forest conditions destroyed, but many trees are killed outright, or die in a short time after injury. The effect on trees is such that they never make any quantity or good quality of timber. They become weakened and are subject to the attacks of rot producing fungi, which eventually complete the destruction. Reproduction of weed species and sprouts from the stumps and the dead trees spring up, thus rendering the area valueless. The evil effects are not confined to the forest alone, but the leaf litter and humus are burned out of the soil, rendering it sterile and subject to erosion.

One may observe the destruction of forested areas, along any of the railroads passing through portions of Lawrence, Scioto, Jackson and Pike counties. These burned areas are particularly observable along the C. H. & D. R. R., between Wellston and Ironton. The dreary, unproductive slopes lining the small streams, along which this road follows, should be so manifest to the casual observer that he may well appreciate the injury to forests by fire.

Injury by Insects. Insects are a more or less harmful factor in forestry, but aside from the damage to black locust by a borer, no serious harm has been noted. The locust borer may usually be found in greater or less numbers wherever the black locust occurs. It is more serious in its ravages in some sections than in others. Its workings are peculiar, and not definitely understood, since it may actually operate in one grove to the extent of ruination, while in others not far removed its presence is scarcely noted. In certain cases young groves are so badly injured as to render them valueless, the trees being so badly riddled that they break off. One instance is on record, where a ten-acre grove containing trees four inches in diameter was totally destroyed.

It is apparent, however, that injury is greater in young trees and that they recover from the effects as they grow older. The following condensed statements on the borer are the observations of competent investigators:

"It is more destructive in some sections and localities than other." "It is noticeably more destructive to some trees than others in the same grove." "It is more destructive in artificial than in natural forests." "It is more destructive to young saplings and to the branches of medium sized trees than to the larger trees." "Very large plantations are only injured around the edges." "Since locust trees are grown for posts, worm holes in the wood cannot be considered as rendering them worthless for the purpose."

(Quoted from, "Locust borers and some results of their work," by Prof. Jas. S. Hine in Ohio Forester, July, 1910.)

It is unfortunate that no successful means are at hand for combating this insect on account of the important role played by the locust in forestry operations. This handicap, while discouraging, should not by any means be instrumental in prohibiting the growing of this species. Groves are being successfully grown notwithstanding the presence of the borer. An excellent treatise on this subject may be found in the number of the Ohio Forester above mentioned.

Leaf Miner. The leaf miner is a small insect which works upon the leaves of the black locust. It eats away the chlorophyll, leaving the skeleton of veins and causing the leaves to turn brown in late summer. This insect is quite widely distributed over southern

Ohio, but has as yet produced no appreciable damage. It no doubt checks the growth of the trees, but has not to our knowledge been responsible for their death.

Catalpa Midge and Sphinx Moth. Defoliation of the catalpa by the larvae of the sphinx moth occurs in parts of Ohio, as well as the killing back of the terminal shoot by the catalpa midge. The latter trouble is fully treated in Bulletin 193 of this Station.

Spraying with any of the reliable insecticides is sufficient to control the sphinx moth. Two broods of this insect sometimes occur, in which case subsequent spraying will be necessary.

Many of our native forest trees are infested with insect enemies in varying degrees, but in no case has injury become serious or general.

Arbor vitae and Norway pine transplants

A White Pine Disease. It is unfortunate that the white pine, so promising in parts of Ohio for forest windbreak and ornamental planting, should be threatened with a serious plant pest known as the pine blister rust, (*Peridermium strobi*) recognized in Germany for thirty years, from which country it has undoubtedly been introduced into the Uniied States. This disease has been noted for some time in America but its importance was not realized until it commenced to menace white pine forest seedlings. In the spring of 1909 the New York Forestry Department called attention to its presence in their nursery, on three-year-old white pine seedlings imported from Germany. It is liable to appear at any place where

white pine seedlings are grown, especially on stock imported from Europe, where it is so abundant in certain portions that the culture of white pine is impossible.

The pine blister rust is known to be one stage of the blister rust of the family ribes, which includes the currants and gooseberries, and in the presence of the two hosts (white pine and ribes) it spreads with considerable rapidity. The disease attacks the bark of young trees and the young stems and branches of older trees, and appears in the form of bright yellow blisters. The infected stem or branch becomes swollen and enlarged. The fruiting bodies finally break through the bark and discharge a dry yellow powder which contains the spores. They may be carried long distances by wind and if brought in contact with currant or gooseberry leaves are liable to produce infection. It is generally assumed by authorities that the spores from the fruiting bodies on the pine cannot directly infect other white pine trees, but require those produced upon currant or gooseberry leaves to produce further infection in the pine.

Damage. Severe damage results where infection of white pine occurs. The injury is more damaging to young trees than to older ones, and there is greater resultant damage to nursery stock. The young trees are liable to succumb outright and older ones are seriously affected. In fact, its presence might make the planting of white pines on a large scale virtually impracticable.

Occurrence. The presence of this disease has not been reported to any extent in this country. It has been found occurring in two Ohio nurseries within the past year, and in these cases on stock imported from Germany. Search for traces has been instituted only during the past year, and whether there has been any general dissemination is not known.

Prevention. Since there is no cause to believe that the disease has been disseminated to any extent, it is important that every effort be made to prevent its futher introduction into this country from Europe. To accomplish this will mean that the greatest care must be exercised in importing European stock. The seriousness of the disease would justify making no more foreign importations, owing to the difficulty in detecting its presence in shipments.

Efforts are under way in this state to take up the problem of prevention and control, and it is hoped that nurserymen handling white pine stock will realize the danger confronting the culture of this species, and will give the state authorities hearty cooperation in their efforts to prevent the spread of the infection.

Descriptions may be had of the disease in Bulletin No. 2 of the New York Experiment Station, Circular No. 38, Bureau of Plant Industry, U. S. Department of Agriculture, and a Bulletin of the

New York State Department of Agriculture, which is a translation of Circular No. 5, of the Imperial Biological Institute for Agriculture and Forestry, (Germany) June, 1905.

Information relative to the above description of this disease was obtained from these sources.

PRICES FOR TIMBER PRODUCTS

The Station is constantly receiving inquiries regarding the best manner in which to utilize forest products and the proper prices attached thereto. This is a difficult question, and one practically impossible to answer satisfactorily. There are many factors influencing the prices of timber and the products into which it should be worked. The former will be contingent upon: 1st. Quantity and quality. 2nd. Proximity to market; the manufacturer can afford to pay higher prices when the timber is near his factory. 3rd. Accessibility; if the timber buyer logs the tract, ease with which he can remove the logs from the woods, the distance to the nearest transportation points, topography, etc., are all to be considered.

Ornamentals in nursery

Timber is frequently disposed of in a manner which is commonly termed "lumping off," i. e., the entire tract is sold in a body. To say the least, this is not advisable, nor fair to either party, especially to the one whose ability is limited in judging the amount of standing timber. Business-like methods would entail the disposal of the timber by applying a standard rule to each log, at a specified price. There should be no objection to this method of sale, as neither party will suffer injustice.

The Station has attempted to obtain prices on timber, but there appeared to be such great variation in different localities and in the same species for different products, that its efforts, so far as fixing arbitrary values are concerned, have resulted in little good to woodlot owners. Furthermore, values obtained for timber in a certain locality have no fixed standard, because of a fluctuating demand; i. e. wood using industries may move from one locality to another so as to be nearer a more available supply of timber, or they may close down for want of raw material.

EDUCATION IN FORESTRY

Education must necessarily be an important feature in progressive forestry. The instructions of the people has been carried on as far as opportunities permitted. Instruction along different lines of work has been given at farmers institutes, granges, picnics and on agricultural trains. A course of lectures was delivered before the "Short Course" students of the College of Agriculture of the Ohio State University. The work has also included lectures at high schools and before various civic and improvement clubs. Womens' clubs have been active in arousing interest and enthusiasm in the care of trees. The Ohio Federation of Womens' Clubs has been an important factor in awakening interest in problems that are especially helpful. During the year 76 addresses were delivered to Ohio audiences of varying number. Much helpful knowledge is also disseminated through the Forest Survey and by the cooperative plan.

RECOMMENDATIONS

To meet the needs of progressive forestry certain changes and additions must be made.

The Station is urgently in need of trained men. The funds available and the salaries paid are not adequate to meet the competition of other institutions, and in consequence it has been impossible to push certain lines of work, because of the lack of assistance. It is matter of no economy to the state to withhold a mere pittance and lose in return opportunities for the developement of one of the State's greatest resources.

Institutional Work. The work at the various institutions has developed to such proportions that a trained assistant is greatly needed to assume charge of this phase. In some cases foremen are required to exercise field supervision and perform the manual labor. Opportunities for experimentation are marked, and such permanence is assured to such work that it hoped the necessary means may be provided to extend this work, and take full advantage of the opportunities offered.

Better Nursery Facilities Required. Better facilities for propagating trees to supply the demand for forest planting at large, and the operations at institutions, are required. The present means are insufficient to properly undertake nursery experiments. A system of furnishing water supply is badly needed, and could be established at very moderate cost.

Shade Tree Investigations. The Station is constantly in receipt of requests for information regarding the planting, care and preservation of shade trees. The greater number of these requests come from cities. A thorough study of conditions inimical to shade and ornamental trees needs to be made. One of the requirements is a relative scale of tolerance to smoke and gases for the various trees used in city planting.

Rate of Growth Studies. This work has been started on a number of species of trees but not completed on any one species. These studies include the examination of many trees of each species. It is a tedious operation and requires considerable time for completion. Such study is near completion for the chestnut, and other commercial species should be taken up in like manner.

A Better System of Cooperation Needed. The work of tree distribution and cooperation with private owners has extended to nearly all parts of the state. The system has operated to good advantage, but the time is ripe for limiting cooperation to those parties who can offer the Station greater advantages. It is desirable to enter into closer contact for the performance of work as planned by the Station. The present system in operation is not entirely satisfactory because it does not compel strict adherence to the directions of the Station.

Demonstration. It is important that the people have more comprehensive and general understanding of the profits that may be derived from forestry, and of means by which land owners may derive a revenue from unproductive areas. Practical demonstration on the ground is required and more men are needed for its accomplishment.

NEEDED LEGISLATION

Ohio is manifestly behind other states in the enactment of forest legislation. While her problems to a certain extent are unique and unlike those of other states, there are certain fundamental principles which apply elsewhere. Aside from this, the enactment of laws peculiar to our conditions is needed.

Better Fire Protection. While Ohio is primarily a state of small farms and woodlands, there are within her borders certain areas preeminently adapted to forestry. These areas lie more or

less within one zone, and on account of their topography and condition of soil are largely unfitted for agricultural pursuits. It would be a good investment for the state to have these areas brought into their greatest possible usefulness. The numerous fires, which constantly menace these areas, are the most discouraging feature in attempting forestry operations. An efficient system of protection is the first requirement. The business of forestry represents an outlay of money which no land owner is willing to make when he feels that there is a big risk attendant thereto. Forestry operations are especially worthy of support, because they entail a long-time investment, and the entering of a field unknown in all its details. The present laws relative to fire protection, while a beginning, are not adequate or sufficient to meet the needs.

Warden Service Necessary. Laws need to be enacted providing for the appointment of fire wardens, whose duties it would be to attend to the prevention and extinguishing of fires in those sections where such service is required. In such regions each township should be permitted to maintain a warden and as many deputies as might be needed.. These wardens may be compensated for the actual time employed in combating and extinguishing fires. Funds required for such work may be appropriated out of the state treasury, or as otherwise provided for.

This system is in successful operation in eighteen states of the Union, and the expense attendant is nominal, since the season in which fires occur is short. It will be necessary that the control of such a system be vested in a chief fire warden, which would logically fall to the office of the State Fire Marshal.

FOREST RESERVES

All forestry operations have thus far been confined to the work carried on with private owners, and the various state or public institutions. While considerable has been accomplished through these sources, they are not sufficient to meet all requirements.

State Forest Reserves. Reserves made in sections of Ohio where the practice of forestry is most desirable, would not only serve as examples to those who desire to manage their tracts in accordance with the principles of forestry, but would induce parties to purchase non-productive areas with this purpose in view. A system of fire protection necessary for state reserves could be extended to the aid of private owners whose land might be adjacent or in close proximity. Thus many thousands of acres of privately owned lands might be made virtual reserves. This method is the most economical measure by which the state could encourage forestry, and such a measure would add greatly to the wealth of

southeastern Ohio. Permanent examples are necessary, and the state must take the initiative. Individuals will not, under existing fire risks.

Large areas are not required nor are they desirable. They should, however, be large enough to permit operations on a basis sufficient to furnish constant employment for the necessary labor.

The Regulation of Stream Flow. The reservation of certain steep slopes adjacent to some of our streams is a matter worthy of consideration, since the question of the regulation of stream flow increases the possibilities of the utilization of water powers—a matter so generally before the public at the present day. The writer is of the opinion that Ohio has possibilities in some of her streams, in this respect, that few realize. Reference may be made to the Walhonding River and some of its immediate tributaries, which have a fall of considerable degree.

With a change in economic conditions brought about by the decreasing supply of our natural fuel resources, more and more will the asset of our water powers be appreciated and utilized. Our rivers will be harnessed to drive the wheels of industry. Tumble down, inefficient mills and dams will be reconstructed on modern principles, replaced with modern equipment, and the power will be multiplied many times.

The reservation of forest areas does not only conserve for practical utility, but also for beauty. Ohio does not possess the great natural resources of our western states in this respect, but there are beauty spots well worth preserving. They may afford advantages to thousands for summer outing as well as a means of protection to wild game.

THE PROTECTION AND JURISDICTION OF SHADE TREES

The desultory planting and care of shade trees, along city streets and on public highways, is everywhere evident, and calls for an efficient system of management. It may seem to many an encroachment on the rights of individuals to take the matter out of the hands of property owners and place it under the supervision of competent authorities, but such action nevertheless would result in the betterment of conditions, by the establishment of trees of suitable species, and giving them the proper care and attention. Would proper supervision of this feature of landscape adornment, bringing into play the best of trees and good management, decrease the value of property? Would it not be the reverse? Any city will bear evidence of a conglomeration of street trees of miscellaneous kinds, planted without regard to adaptability, and so close together that they become distorted and unsightly. To add to this the lack of system and

A 25-year old black locust planted in the woods. The trunk is free from borer wounds

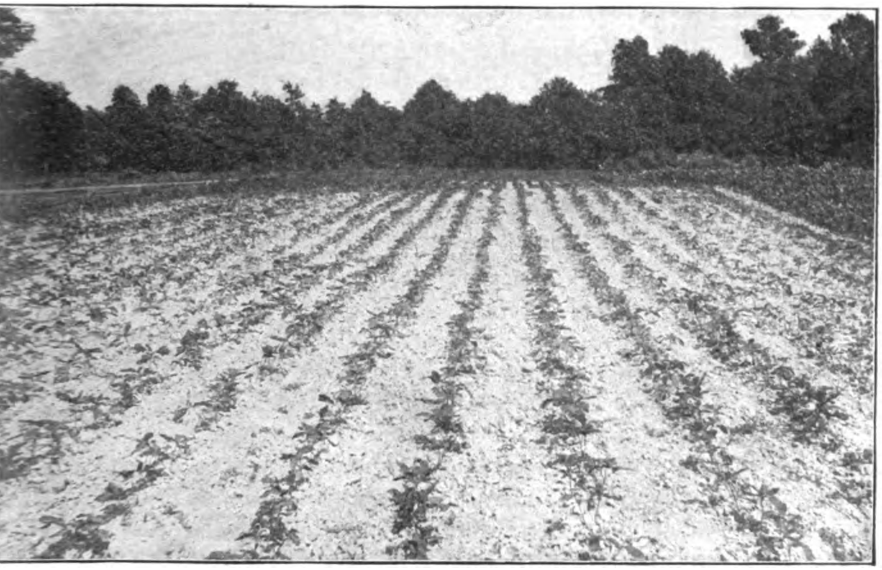
intelligence in pruning makes the adjacent telphone pole pleasing in comparison. The planting of certain species of rapid growing trees without regard to other assets has often led to lack of results. The right growing of trees requires knowledge and professiona manipulation.

FOREST PARKS

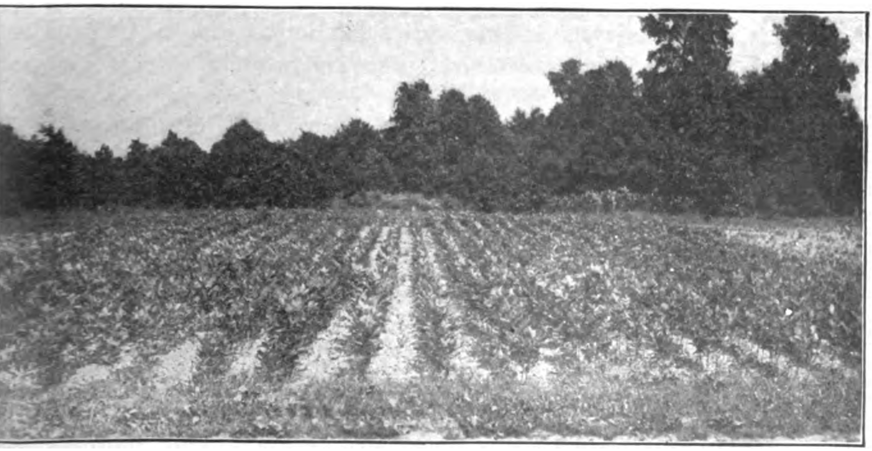
European countries possess forests which are utilized both for public parks and the production of timber, obtaining in this respect the advantages of the natural forest, which is the most satisfying and pleasing of all, and at a cost far below that of the artificial, costly city parks. Under European system, cities and towns are permitted to acquire lands for park and forest purposes, under supervision of the goverment forestry authorities.

Our present laws permit cities to purchase land for parks, but provide that such areas must be contiguous to corporation limits. This may not only prevent the securing of suitable lands, but may involve a greater expenditure than would be required for areas farther removed, but which might be better adapted to the purpose. Such parks would not only offer advantages to thousands of city people for outing, instilling in them a love for trees and nature, but in time would prove excellent revenue producers. There could be no better means of alloting to those who dwell in cities their share of the advantages offered by forestry, and thereby inducing a higher moral tone, and offering an opportunity to discover the secrets of the woods. To the rising generation it would be a source of education not contained in books nor lectures, an inspiration to nobler and higher manhood and womanhood. It would incite a higher regard for the forest, flowers, birds and all creatures of nature, so that at length their preservation and right use might be made sure. Their soothing influence may extend to thousands of tired and nerve-shaken, people.

"Real conservation involves wise, non-wasteful use in the present generation, with every possible means of preservation for succeeding generations; and though the problem to secure this end may be difficult, the burden is on the present generation promptly to solve it, and not to run away from it as cowards, lest in the attempt to meet it we may make some mistake. The problem is how to save and how to utilize, how to conserve and still develop, for no sane person can contend that it is for the common good that Nature's blessings should be stored only for unborn generations."—President Taft, in address before the Second Conservation Congress.



Red oak transplants



White ash transplants

SUMMARY OF RECOMMENDATIONS.

1. More men of technical training are needed.
2. The work at the institutions should be extended.
3. The forest nurseries should be increased to greater capacity on account of the demand for forest seedlings.
4. The relative tolerance of smoke and gases for trees used in city planting should be determined.
5. Studies of the rate of growth of various commercial trees are necessary for the development of a sound policy of woodlot management.
6. Cooperation with private owners, in the matter of furnishing trees and conducting experimental work, should be confined to those parties who can offer the Station the greatest facilities.
7. An educational campaign is needed to disseminate forestry information and to conduct field demonstrations.
8. A better system for fire protection should be established in certain sections. To accomplish this will necessitate a warden service.
9. Forestry reserves are necessary for experimental and demonstrational forestry, and should be established in certain parts of Ohio. They would serve to put thousands of acres of privately owned land under conservative management, and would in time prove excellent investments for the state.
10. The regulation of stream flow is a matter worthy of consideration, since it will influence the efficiency of water power. In some cases the slopes bordering streams, should be reforested and held in reservation.
11. A better system of caring for city and public highway shade trees is required. This matter should be taken out of the hands of private owners, and given to either state or municipal authorities.
12. Cities and towns should be allowed to assist in the cause of forestry by the establishment of forest parks to be useful both as examples of forestry practices, and as parks and playgrounds.

APPENDIX

LAWS OF OHIO RELATING TO FORESTRY

DEPARTMENT OF FORESTRY AT THE EXPERIMENT STATION

SECTION 1166. There shall be a department of forestry at the state agricultural experiment station under the supervision and management of the board of control. **Department of forestry**

SECTION 1167. The board of control shall carefully inquire into the character and extent of the forests of the state, the causes of their waste and decay, and methods for their preservation and development. It shall conduct investigations in the several sections of the state, determine the species of valuable trees best suited to grow on the various kinds of soil, and ascertain the best methods and cost of the propagation, planting and cultivation of woodlots and plantations. It shall determine the average rate of growth of the various species of trees and the relative values of different kinds of timber for domestic and commercial purposes, and conduct experiments for the purpose of increasing durability of the various kinds of wood; determine the kind of trees and shrubs best suited to different localities for wind-breaks and shelter, and for beautifying grounds, and ascertain the best methods of planting and managing them. **Duty of board of control**

SECTION 1168. The board of control may cooperate with the department of agriculture of the United States in conducting such portion of the work mentioned in the preceding section as may be agreed upon by the board of control and such department of agriculture. **Cooperation with United States department of agriculture**

SECTION 1169. The members of the board of control shall perform the duties required of them in the department of forestry without compensation. The expenditures by the state for cooperative work of such department shall not exceed the amount expended by the department of agriculture of the United States for such purpose. **Expenditures**

SECTION 1170. From time to time the board of control shall issue bulletins and publications containing information and recommendations upon subjects mentioned in the preceding sections relating to forestry. It shall make an annual report to the governor of the work performed under such sections. It shall embody in the report any recommendations and suggestions it deems proper relating to legislation for the development of a system of forestry. **Bulletins and annual report**

FOREST FIRES

SECTION 7496. If the woods or prairies in a township are on fire so as seriously to endanger property, the trustees of such township may order as many of the inhabitants of the township, liable to work on the highways, and residents in the vicinity of the fire, as they may deem necessary, to repair to such place and assist in extinguishing it, or stopping its progress. **How fires in woods or prairies extinguished**

SECTION 7497. A person so ordered shall be allowed, by the superintendent of his road district, to be applied on his toll or road tax, a like amount per day as he is allowed for work on public highways. **Allowance for same**

SECTION 7498. If a person refuses or willully neglects to comply with such order, he shall forfeit a sum not less than five dollars nor more than fifty dollars, to be collected before any justice of the peace of the township. **Penalties for refusal to assist**

FOREST FIRES CAUSED BY RAILWAY LOCOMOTIVES.

Spark arresters

SECTION 8966. Except in the months of December, January and February, any company or person operating a railroad or a part of one, shall place on every locomotive engine used therefor, or in construction or repairing the road, such device or contrivance as most effectually will guard against the escape of fire or sparks that otherwise would be thrown out by such engines, and keep the device in good repair.

For-feiture under preceding section

SECTION 8967. A railroad company, corporation or person violating the provisions of the next preceding section, upon conviction thereof in a court of competent jurisdiction, shall forfeit and pay for each violation any sum not exceeding one hundred dollars. In addition thereto the court of common pleas in a county through which such railroads are constructed and operated, may enjoin such companies, corporations or persons from using on such railroads, a locomotive not provided with the device hereinbefore required.

Company must keep right of way free from combus-tible material

SECTION 8968. Every company, or person in charge of a railroad as manager or receiver, shall keep the right of way clear from weeds, high grass, and decayed timber, which from nature or condition are combustible, and liable to take or communicate fire from passing locomotives to abutting or adjacent property. Such company shall be liable for all damages sustained by the owner or occupant of such property from carelessness or neglect to keep its right of way clear of such combustible material.

When abutting owner may remove combus-tible material

SECTION 8969. In case of failure to comply with the above requirements, a person owning or controlling property abutting on or adjacent to a railroad right of way, after twenty days' notice in writing, the default still continuing, may cause all combustible material to be removed from the right of way along or by such property. Upon presentation of a reasonable account therefore to the agent at the nearest station of such company or receiver, if it or he refuses to pay the amount asked, within thirty days, it may be recovered before any court having jurisdiction thereof.

Loss or damage by fire; evidence

SECTION 8970. Every company operating a railroad or a part of one shall be liable for all loss or damage by fires originating upon the land belonging to it caused by operating such road. Such company further shall be liable for all loss, or damage by fires originating on lands adjacent to its land, caused in whole or part by sparks from an engine passing over such railroad, which may be recovered before any court of competent jurisdiction within the county in which the lands on which such loss or damage occurs are situated. The existence of fires upon the railroad company's lands is prima facie evidence that they are caused by operating such railroad.

Prima facie evidence as to neg-ligence

SECTION 8971. In actions against a person or incorporated company, to recover damages to property, real or personal, from fire communicated by a locomotive engine on or passing along a railroad, the fact that such fire was so communicated, is prima facie evidence to charge the corporation or persons then occupying and using such road, as owners, lessees or mortgagees, and also those who had the care and management of such engine, with negligence.

MALICIOUS OR NEGLIGENT STARTING OF FOREST FIRES.

SECTION 12436. Whoever maliciously or negligently sets fire to woods, prairies, or grounds, not his property, or maliciously permits fire to pass from his prairies or grounds to the injury or destruction of the property of any other person, shall be fined not more than one hundred dollars, or imprisoned not more than twenty days, or both. Maliciously setting fire to woods, prairies, etc.

THEFT OF TIMBER.

SECTION 12455. Whoever saws, bores or cuts down timber, trees or hoop-poles, standing or growing upon the lands of another or lands of the state, or unlawfully takes, carries or hauls away from the lands of another or lands of the state, timber, saw-logs, rails, rail-cuts, tan-bark, hoop-poles, railroad ties, hoops, staves, stave-bolts, blocks or butts or timber of any value, or unlawfully digs up, plucks or carries away from the lands of another, a cultivated root, plant, fruit or other vegetable production, with intent to injure the owner of said lands in his property or to defraud him, if the value of the property so severed or taken is thirty-five dollars or more, shall be imprisoned in the penitentiary not less than one year nor more than three years, and if the value of the property so severed or taken from the lands is less than thirty-five dollars, shall be fined not less than twice the value of the property so severed or carried away or imprisoned in the jail of the county not more than thirty days, or both. Cutting and stealing timber

SECTION 12456. Whoever buys any of the property mentioned in the next preceding section, knowing that it had been unlawfully severed or taken from the lands of another or from the lands of the state with intent to defraud the owner thereof, shall be fined not less than twice the value of the property so bought or received, or imprisoned in the jail of the county not more than thirty days, or both. Buying timber unlawfully cut

SECTION 12457. Whoever, owning a saw-mill, stave, spoke or other manufactory of wooden articles, or having charge or control thereof, or working in or running a saw-mill, stave, spoke or other manufactory of wooden articles, saws or knowingly permits to be sawed or used in such mills or manufactories, timber, logs or other lumber with intent thereby to injure or defraud the owner of such property, and knowing that such timber, logs or other lumber had been severed or taken from the lands of another or from the lands of the state in violation of the provisions of section twelve thousand four hundred and fifty-five, shall be fined not less than twice the value of the lumber, logs or timber so sawed, or imprisoned in the jail of the county not more than thirty days, or both. Using timber unlawfully cut

SECTION 12458. The court trying a cause arising under the next three preceding sections, shall instruct the jury to find the value of the property severed or taken from the land, bought, received, sawed or manufactured in violation of any provision of said sections, and shall render judgment against the person convicted for the amount of fine assessed and cost of prosecution. Judgment in such cases

SECTION 12459. The sheriff or other officer collecting said judgement after paying all costs of prosecution, shall pay over to the owner of the property so severed or taken, twice the value thereof as returned by the jury. Duty of the sheriff

VIOLATION OF TRADE-MARK

Carrying away timber having a trade-mark

SECTION 12060. Whoever knowingly and unlawfully takes and carries away, secretes, destroys or converts to his own use timber upon which is stamped, branded or impressed a trade-mark, the owners of which have complied with the laws of this state in relation to trade-marks, if the value of the timber is thirty-five dollars or more, shall be imprisoned in the penitentiary not less than one year nor more than seven years, or, if the value thereof is less than that sum, shall be fined not more than two hundred dollars or imprisoned not more than thirty days, or both.

CUTTING TIMBER BELONGING TO STATE

Trespassing on state lands

SECTION 12498. Whoever, without authority, enters upon land belonging to or held in trust by this state, and cuts down standing timber or removes therefrom stone or timber, the property of the state, shall be fined not more than fifty dollars and imprisoned in jail not more than ten days. Such prosecution shall be by indictment in the court of common pleas.

THE REJUVENATION OF ORCHARDS

REPORT OF SPRAYING EXPERIMENTS IN SOUTH-EASTERN OHIO—1910.

OHIO Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., DECEMBER, 1910.

BULLETIN 224

Sprayed with standard Bordeaux

Sprayed with lime-sulfur

The Bulletins of this Station are sent free to all residents of the State who reqest them. When a change of address is desired, both the old and the new address should be given. All correspondence should be addressed to EXPERIMENT STATION, Wooster, Ohio

OHIO AGRICULTURAL EXPERIMENT STATION

The Station.

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[1]In cooperation with U. S. Weather Service.
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[3]In cooperation with Boys' Industrial School. [4]In cooperation with Ohio State Reformatory.
[5]In cooperation with Ohio Institution for Feeble Minded Youth.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 224 DECEMBER, 1910.

THE REJUVENATION OF ORCHARDS

REPORT OF SPRAYING EXPERIMENTS IN SOUTH-EASTERN OHIO—1910.

By F. H. BALLOU

Explanatory: The work of the Horticultural Department of the Ohio Experiment Station, reported in the pages which follow, was conducted, during the season of 1910, under conditions existing in south-eastern Ohio—an area of which Washington county may be said to be the center and characteristically representative.

While the weather conditions of the spring of 1910 were very trying in this particular part of Ohio, the cold was still more severe farther north and west, practically cutting off the apple crop in the north-central, western and south-western counties. The cold was somewhat less severe in the more southern counties of the state where, with a few exceptions, a record-breaking crop of apples of fine quality was harvested.

It may be well, in addition, to explain that the first work done by the Experiment Station in south-eastern Ohio was during the season of 1909, when three small experiments in spraying were conducted at Belpre, Little Hocking and Armenia (see Bulletin No. 217). At that time there had been no thorough, scientific spraying done by individual orchard owners in this once famous apple-growing section. Destructive insects and fungous diseases had, for ten years or more, destroyed the crops annually.

The Station's initial work in 1909 brought marvelous results in sound, beautiful fruit and an abundance of it, while the unsprayed orchards, as before, bore but very light crops of worthless, scabby culls.

In 1910 many orchard owners, determined to benefit by the object lessons which they closely observed in the Station's work of 1909, purchased spray outfits and did valiant battle against their now recognized enemies, codling worms, apple scab and sooty

TIMOTHY

Timothy (*Phleum pratense*) is a native of Europe having been brought to this country by the early colonists. It takes its name from one Timothy Hanson who introduced it from England in 1720. Its success under cultivation in various parts of the new country led to its being carried back to England some thirty or forty years later, the new name going with it. The old name for this grass was Meadow catstail. It is doubtful whether it had been cultivated in England previous to this importation from the colonies.

Timothy is also known as Herd's grass in New England from the fact of its having been introduced in New Hampshire at an early day by John Herd.

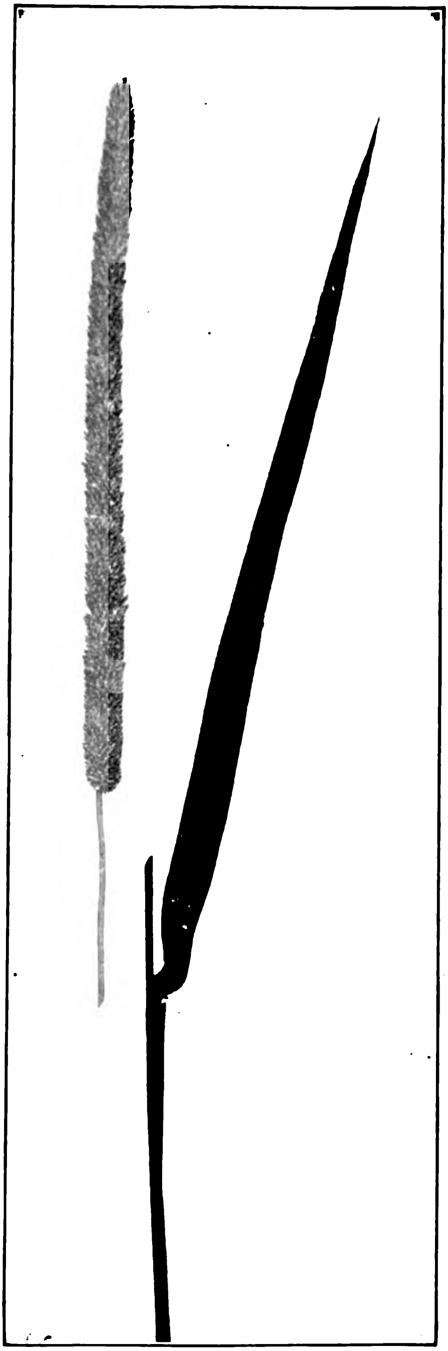
It is a hardy perennial, having erect stems, with a bulbous enlargement at the base of the stem. It is inclined to form tufts or stools, new stalks starting from the base of the original plant. In plant breeding work especially desirable plants are frequently multiplied by detaching and transplanting these bulbs.

Timothy is more generally cultivated in Ohio, and in the United States as a whole, than any other grass. Indeed, in so far as Ohio is concerned, probably more than all other grasses combined. It is adapted to a great variety of soils, though it does best upon rich, moist loams and clays. Upon light, sandy soils it is not as successful.

Timothy is distinctly a grass for hay rather than pasture. It may be used in pasture mixtures for early or temporary pasturage, but it will soon give place to the better sod-forming grasses, as it does not take kindly to close grazing and tramping. As a meadow grass, however, it stands at the head.

Rotation: Timothy is grown by many farmers in a four or five year rotation, being seeded with clover in wheat or oats. The first year of meadow, clover is the principal crop; the second year, timothy predominates. Near good city markets it is often grown year after year without reference to rotation, good yields being maintained by annual dressings of manure or other fertilizers. Timothy, like other sods, is valuable in maintaining the humus supply of the soil. Such sods are usually plowed for corn. Old sods are likely to be infested with insect pests and should be plowed if possible during freezing weather.

Seeding: Timothy is commonly seeded with wheat in the fall, clover being added in the spring. Under these conditions the timothy is likely to crowd the wheat if for any reason the latter does poorly. It does not give the clover as good a chance as when both



Timothy

are seeded together in the spring. Regardless of the other crops, however, fall seeding gives results more favorable to timothy than spring seeding. It is frequently seeded with oats or barley.

There is no more favorable time to seed timothy or other grasses than in July, August or early September. To be successful, clean, well compacted and moist seedbeds are essential. Under such conditions no nurse crop is needed. A full crop of hay may be expected the following season. Fifteen pounds of timothy may be counted a full seeding when used alone. When clover is used with the timothy, six to eight pounds of the latter, seven pounds of red clover and three pounds of alsike clover have been found satisfactory at this Station. Unless seeded during freezing weather when the ground is cracked open with frost, the seed should be covered with a light harrow or weeder. When seeded with wheat or oats it can be distributed through the grass seeding attachment of the grain drill and dropped in front of the drill hoes.

Harvesting: Many experiment stations have tested the value of timothy cut at different stages of growth. Briefly summarized these results show that the total dry matter increases until the seed is close to maturity; that the total protein and fat, as well as the digestibility of the different nutrients decrease slightly after timothy passes full bloom; that the fiber and nitrogen-free extract increase during this period. All things considered timothy may safely be left until shortly after the blossoms have fallen, but not later than when the seed is in the dough. Comparatively late harvesting is favorable to rapid curing and consequently lessens the danger of loss from rain, with the alternate dissolving of soluble feed elements and bleaching in the sun, so destructive to quality and palatability. With good weather and the use of the hay tedder, there is little difficulty in curing and storing timothy in the barn or stack the day it is cut. If weather is settled, some time is saved by mowing it late in the afternoon before.

Yield: In tests at this Station, timothy has led all other grasses in yield per acre. In 1905, the yield of hay was 2.92 tons per acre; in 1906, 2.62 tons; in 1907, 3.60 tons. The test plots were plowed up in 1908 and new seedings of all the different grasses tested were made July 1, 1909. In July, 1910, the new seeding of timothy gave a yield of 4.85 tons per acre of thoroughly cured hay. The four year average yield is 3.497 tons per acre.

Composition: The composition of timothy hay as grown upon the Station farm is shown in table IV. These determinations were made by the Department of Chemistry. It will be noted that the

percentage of protein is lower in timothy than in the other grasses. The percentage of fat, however, is the highest of any of the grasses. The food value per acre is shown in the same table.

The popularity of timothy among Ohio farmers is easily accounted for. It lies in its good yield; in its palatability; in the ease and cheapness with which it is harvested; in the great demand at good prices for timothy hay; in the moderate expense of seeding an acre to timothy; in the good germination of seed and the relative certainty of securing a stand, and in its longevity when properly cared for. With annual dressings of manure or, in the absence of manure, of nitrate of soda supplemented with acid phosphate and muriate of potash, and, when needed, lime, timothy may be made to give good yields of hay indefinitely. Ordinarily this would not be desirable, but under certain conditions it is admissible.

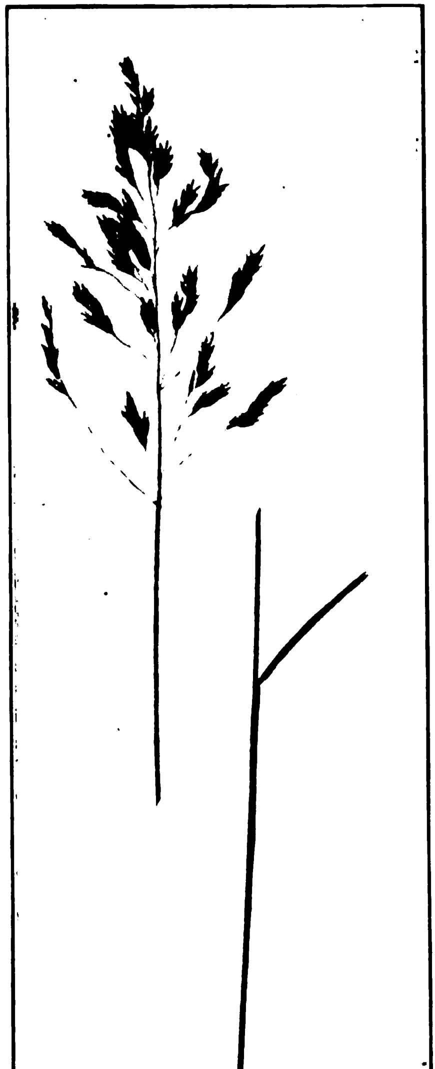
Disadvantages: In common with all the grasses timothy is lacking in ability to utilize the nitrogen of the atmosphere through the aid of such micro-organisms as cooperate with clover and other legumes, and is consequently a much more exhaustive crop on land than clover. While timothy cannot take the place of clover in a rotation, it should be recognized that the grasses leave crop residues in the way of sods of great value in maintaining the supply of humus.

In so far as furnishing a crop of aftermath is concerned, timothy can not be counted upon to do very much, of an average season. Only in case of exceptional rainfall during July and August may a second crop worth harvesting be expected.

The Production of Seed: As a seed producer timothy is usually to be depended upon. The yields seldom drop below five bushels per acre and frequently reach ten or twelve bushels. It can be harvested with the ordinary farm machinery. It is cut with a grain binder; at once put in shock "two by two", without caps, and allowed to cure about a week, when it may be threshed with a common grain separator, using special sieves.

BLUE GRASS

Kentucky blue grass (*Poa pratensis*), very commonly called June grass, and in England, smooth-stalked meadow grass, is native to both Europe and North America. It is a hardy and persistent perennial well distributed over the state, holding the position as a pasture grass which timothy holds as a grass for hay. It makes the best sod of any of our grasses and tends to crowd other grasses out when land is left any considerable time in grass, particularly if it be pastured.



Blue grass

Soil: It is at its best on the limestone soils of the state, though it does fairly well on a wide range of soils in the timothy and clover region. It does better on clay than on sandy loams. Being a shallow-rooted plant it gives way quickly to droughty conditions, though it will start up immediately after good rains.

Blue grass is not well adapted to rotation farming. It is seldom used for hay, though it makes a very nutritious hay as will be seen by refering to Table IV. Unless it is harvested promptly it inclines to be wiry and loses in palatability.

It is both an early spring and a late fall grower, furnishing excellent pasture at both ends of the season. Its short season is in midsummer, particularly if the weather be dry. It stands grazing and tramping well, but it is a mistake to graze it too close.

Seeding: Blue grass may be seeded with wheat in the fall, or in early spring along with other grasses and clover, but probably the best time to seed it is in the late summer or early fall, either alone, or with other grasses. Ordinarily there is difficulty in securing an immediate stand of blue grass. This is due in part to the very general poor germination of blue grass seed. When only a small percent of the seed germinates it must needs take time for blue grass to make its way. With good seed sown under favorable conditions blue grass will take possession of the ground quite rapidly, though not as rapidly as many grasses. A seeding made by this Station July 1, 1909, cut 2.86 tons of well cured hay June 20, 1910. The sod now fifteen months after seeding is very dense. This seeding was at the rate of 25 pounds per acre.

It is important that grass seed be tested for germination before purchases are made. If this be done there will be fewer purchases.

As blue grass seed runs, it probably is as well to seed other grasses with it. This reduces the chances of failure and insures an immediate crop. The blue grass will eventually come into possession of the ground. A mixture of blue grass, timothy, redtop and orchard grass seeded in the late summer or fall, followed in the early spring with seedings of red and alsike clover, will be found satisfactory. If the seeding be made early it will not be amiss to sow the clovers with the grasses. For the amount of seed recommended of the several constituents see a later page on the care of pastures.

When seeded alone, 25 or 30 pounds of blue grass should be used per acre.

Yield of Hay: This Station has secured a four year average yield of 2.187 tons of hay per acre. The lowest yield during the four years was 1.56 tons and the highest 2.86 tons. As grasses go this is not a bad showing.

The seed production of blue grass is largely confined to a small area in Kentucky. Special machinery is used for "stripping" the heads, as also for cleaning the seed.

For Lawns: Blue grass is the basis of all lawn grass mixtures. It stands frequent clipping admirably. Its one weakness is its habit of turning brown in dry weather, but when water can be supplied it leaves little to be desired. It is well to mix redtop and a little white clover with it, however. A mixture of 30 pounds of blue-grass, 15 pounds of redtop and 3 pounds of white clover per acre makes a good seeding.

REDTOP

Redtop (*Agrostis alba*) belongs to a family of grasses very generally distributed over the globe. While probably second in Ohio to timothy, as a grass for hay, and to blue-grass for pasture, it is not a close second in either case. It is a hardy and a long-lived grass, making a heavy, tough sod which stands tramping well.

It is about equally valuable for hay and pasture. It is a little later in season than timothy but may be seeded with it in so far as harvesting is concerned, though where hay is intended for market this practice can hardly be advised for redtop is not in as good market demand as timothy.

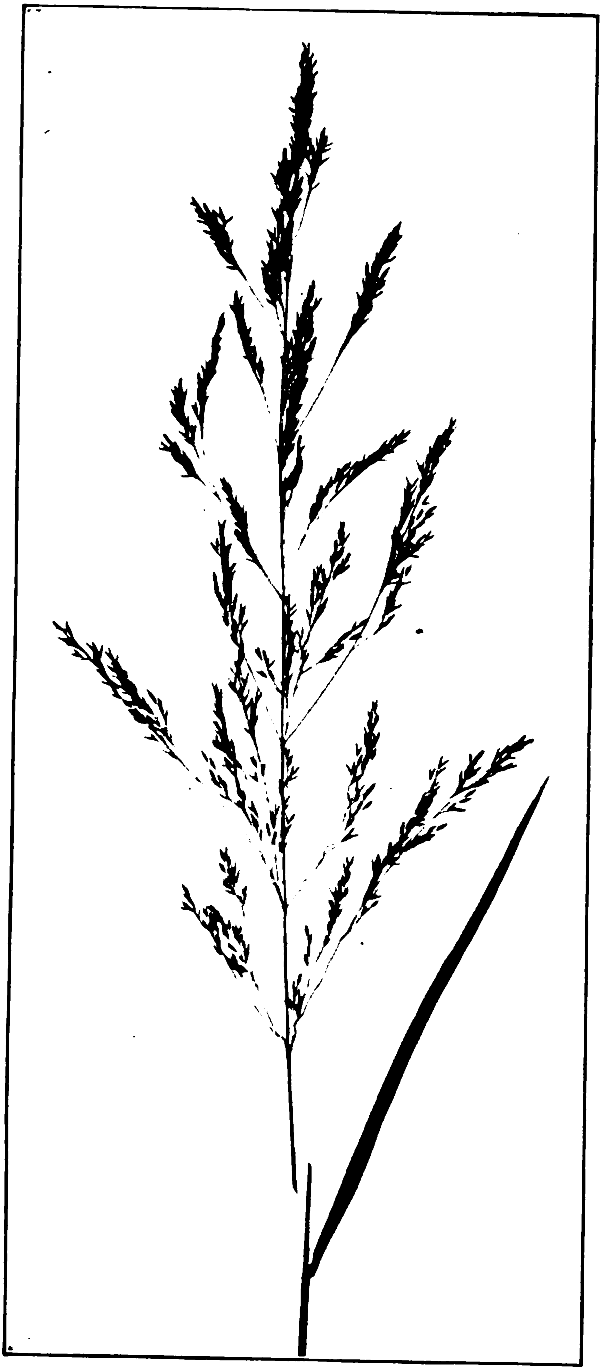
Soil: Redtop is very generally found growing wild on wet, heavy bottom lands, and should always be included in mixtures for such lands whether for hay or pasture. It will do well on soil that is too acid for clover or timothy to thrive. While better adapted to wet lands it may be expected to do fairly well on a great variety of soils.

Seeding: Redtop seed varies rather more in quality than other grasses. Quotations at hand from a single seedsman vary in price from $4.00 to $16.50 per cwt., owing to grade. The best recleaned seed is the cheapest. Fancy grades weigh from 30 to 40 pounds per bushel.

Of the best grade of seed 15 pounds per acre may be counted a full seeding, when used alone.

It may be seeded as has been recommended for timothy and blue grass.

Land which for any reason cannot well be prepared for seeding may be seeded in February or March, the seed being covered by freezing and thawing. Thin or recently cleared woodlands may be set in grass in this way. Also wet lands with inferior herbage may be improved by such seeding. Fowl meadow grass (*Poa flava*), sometimes called false redtop, may well be mixed with redtop for the latter conditions.



Redtop

For the sake of variety and season, redtop should be included in all pasture mixtures.

Yield as Hay: As tested at this Station for yield of hay redtop has given a four year average yield of 2.817 tons per acre. It accordingly stands second of the eight grasses tested this length of time. It is exceeded in yield by timothy only.

ORCHARD GRASS

Orchard grass (*Dactylis glomerata*) is a native of Europe, going by the name of cocksfoot in England. Its American name is due to its successful and persistent growth in partially shaded places.

This grass has but a small place in Ohio agriculture. In two counties, Clinton and Highland, it is grown extensively as a seed crop, but is not extending very far over their borders. The price of orchard grass seed is usually quite high and the returns per acre fairly remunerative; but this matter of seed production could easily be overdone, as the demand is limited.

Orchard grass is about equally valuable for hay or pasture. It calls for a drier soil than redtop. It does best on rich, well drained loams.

Its Advantages are: It stands drought much better than timothy and blue-grass. It is one of the first grasses to start in the spring, offering the first bite of the season in pastures. It makes a more rapid growth after mowing than most grasses, furnishing considerable aftermath for pasturage and, some seasons, a fair second cutting. It is very persistent. The writer knows of patches seeded 35 years ago that seem not to have changed any during the last 25 years.

Its Disadvantages are: Unless kept closely cropped in pastures it is likely to be avoided by livestock, as it seems to lose in palatability with size and age. Unless cut for hay promptly (when in blossom) it rapidly deteriorates, becoming very woody. In this woody stage it is not relished by stock. On this account its harvest season cannot be extended like timothy. The tendency to grow in tufts is much greater with orchard grass than with other grasses. It is very difficult, if not impossible, to secure an even sod. It costs about three times as much to seed an acre to orchard grass as to timothy. On the average, at this Station, timothy has exceeded orchard grass in yield of hay about 60 percent. The market for timothy hay is established and the price is at the top; neither of which is true of orchard grass.

Seeding: Orchard grass may be seeded on wheat ground in the early spring and the covering left to the freezing and thawing of the ground, but perhaps a better way is to wait until ground is dry

Orchard grass

enough to put a smoothing harrow on it, thus insuring a better covering, as this seed will not drop into the ground as readily as timothy and clover. It is sometimes seeded with wheat in the fall. Like other perennial grasses it is found very satisfactory to seed it in midsummer or early fall, alone or with other grasses.

The purity and germination of commercial samples of orchard grass are usually good. When seeded alone either for hay or pasture it is well to use about 30 pounds of seed per acre. For growing a seed crop less seed is used—12 to 20 pounds.

Since orchard grass is of the same season as red clover it is often recommended to seed the two together. That this mixture will produce any more or any better hay than mixtures of timothy and clover, is to be doubted, even though the latter are not of the same season. The Illinois Station* found a mixture of 9 pounds of timothy and 6 pounds of clover to yield 18 percent more hay, as an average of two years' tests, than 17½ pounds of orchard grass with the same amount of clover seed.

If orchard grass has a place in Ohio as a hay crop it is in locations where timothy is not at its best—in partially shaded places, for instance. It is worthy of trial, in a small way, in pasture mixtures

Seed Production: In the seed producing sections orchard grass is allowed to stand until it begins to shatter slightly, when it is cut with a grain binder, as high as possible. It is allowed to stand in small shocks 2 or 3 weeks, when it is threshed with an ordinary grain separator. It yields from 8 to 16 bushels of seed per acre. The aftermath is used for pasture or hay. The straw also has a little value.

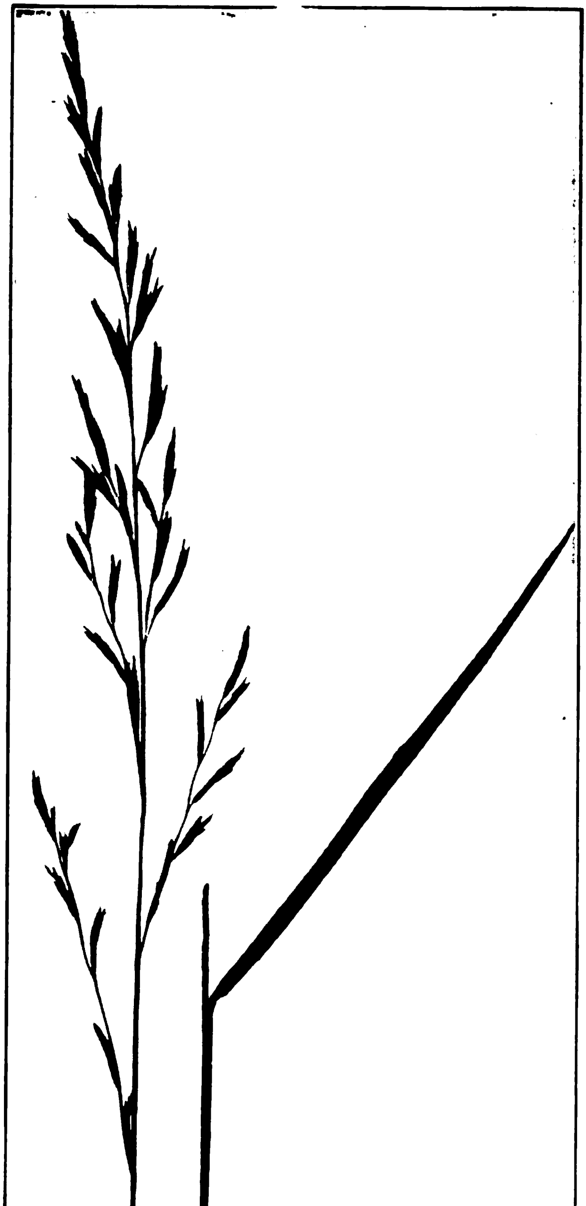
Yield of Hay: The four year average yield of hay at this Station has been 2.197 tons per acre.

MEADOW FESCUE

Meadow fescue (*Festuca pratensis*) is a native of Europe and is very extensively cultivated in England. It is seldom seeded in Ohio, but in some way it has become quite well distributed over the state along road sides and, to some extent, in the richer and more moist portions of permanent pastures. This suggests its adaptability to certain Ohio conditions and is perhaps its chief recommendation.

In the timothy region there can be but little place for it as a hay. It is far below timothy in yield and unless it be cut promptly is inclined to be tough and wiry. When harvested properly it makes a palatable hay.

*Bul. 15, p. 486.



Meadow fescue

It is doubtless better as a pasture grass, though it is not well enough tested yet to justify its unqualified recommendation. One great objection to it is the high price of the seed. A full seeding calls for about 30 pounds per acre. At present prices this will cost double what it will to seed to a mixture of blue-grass, timothy and redtop, and, as tested at the Cornell Experiment Station,* the latter mixture will prove the more valuable.

TALL FESCUE

Tall fescue (*Festuca elatior*) is another member of the Festuca family of which there are some eighty species. This grows four to eight inches taller than the meadow fescue and is somewhat more vigorous. The seed of the tall fescue comes still higher in price. In yield of hay it is superior to meadow fescue. In quality they are about the same.

At this Station the four year average yield of tall fescue is 2.435 tons per acre, while the average yield of meadow fescue is 2.10 tons. Each year of the four, the tall fescue has led in yield.

BROME GRASS

Brome grass (*Bromus inermis*), frequently called awnless brome grass and Russian brome grass, is a native of Europe, having been grown upon the cold, dry Steppes of Russia for centuries. As compared with other grasses it is a recent introduction in this country. It is proving a great acquisition in the northwest and parts of the west. Its value for Ohio conditions remains to be proved.

Brome grass is in greater repute as a pasture than as a hay grass. It has a very deep and an abundant root system which fortifies it against drought.

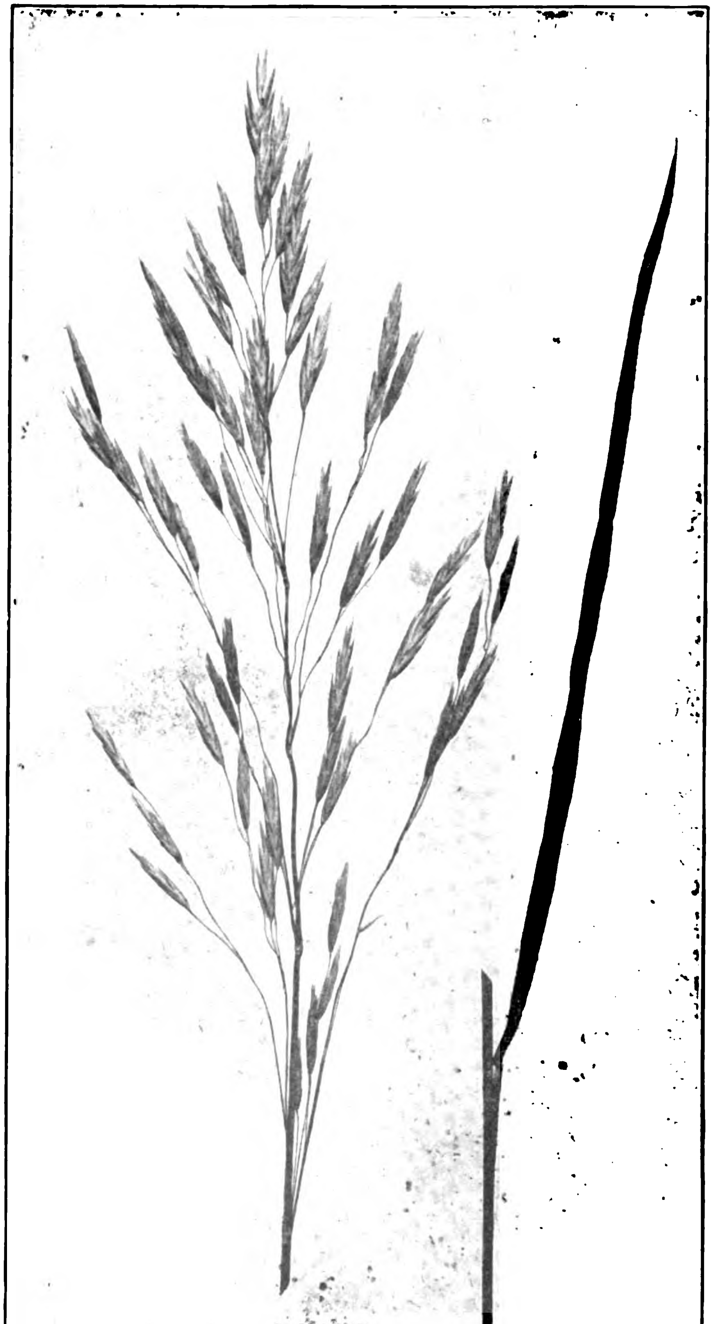
The Ohio Station has been quite unfortunate in its seedings of brome grass. Owing to poor germination of seed, in part, it has failed upon repeated seedings. A seeding made in 1909 was the first to give a fair result.

The Cornell Station† reports a failure after three different seedings, and a lack of adaptability to New York conditions.

Seeding: Twenty pounds of seed per acre is quite commonly recommended for this grass. All things considered it would seem to be far short of a full seeding. The seed of brome grass is very large. It runs about 140,000 seeds per pound, while blue-grass has some 2,500,000, and redtop 6,000,000 per pound. Forty pounds of brome grass seed per acre will come nearer a full seeding for Ohio conditions. The seed is moderate in price.

*Bul. 280, p. 378.
†Bul. 280, p. 379.

Tall fescue



Brome grass

Yield: The only year this Station has succeeded in getting a crop of brome grass was in 1910. The yield of hay was 2.98 tons. The same season timothy gave a yield of 4.85 tons; redtop 3.34 tons tall fescue 3.02 tons and blue grass 2.86 tons per acre.

Brome hay is nutritious and palatable.

TALL OAT GRASS

Tall oat grass (*Arrhenatherum elatius*) is a European perennial grass, little cultivated in this country. There would seem to be small, if any place for it in this state, save possibly on light, sandy soils where better grasses will not thrive. It is a deep-rooted grass and stands drought well.

In point of season tall oat grass ripens with orchard grass, or a little earlier. Like orchard grass it deteriorates rapidly after it is ready for harvest. It ripens seed quickly and shatters badly. It starts growth very early in the spring and produces a great deal of aftermath when cut for hay.

In palatability it is subject to great criticism. As grown at this Station it has shown quite a tendency to smut. The yield of hay has been fairly good, the four year average yield being 2.247 tons per acre. Only once in the four years has the yield dropped below two tons.

THE RYE GRASSES

Perennial rye grass (*Lolium perenne*) is a native of Europe. It is a great favorite in England and perhaps the most important grass of Europe. It is valued very highly as a pasture grass and is used to quite an extent for hay also, though it is preeminently a pasture grass.

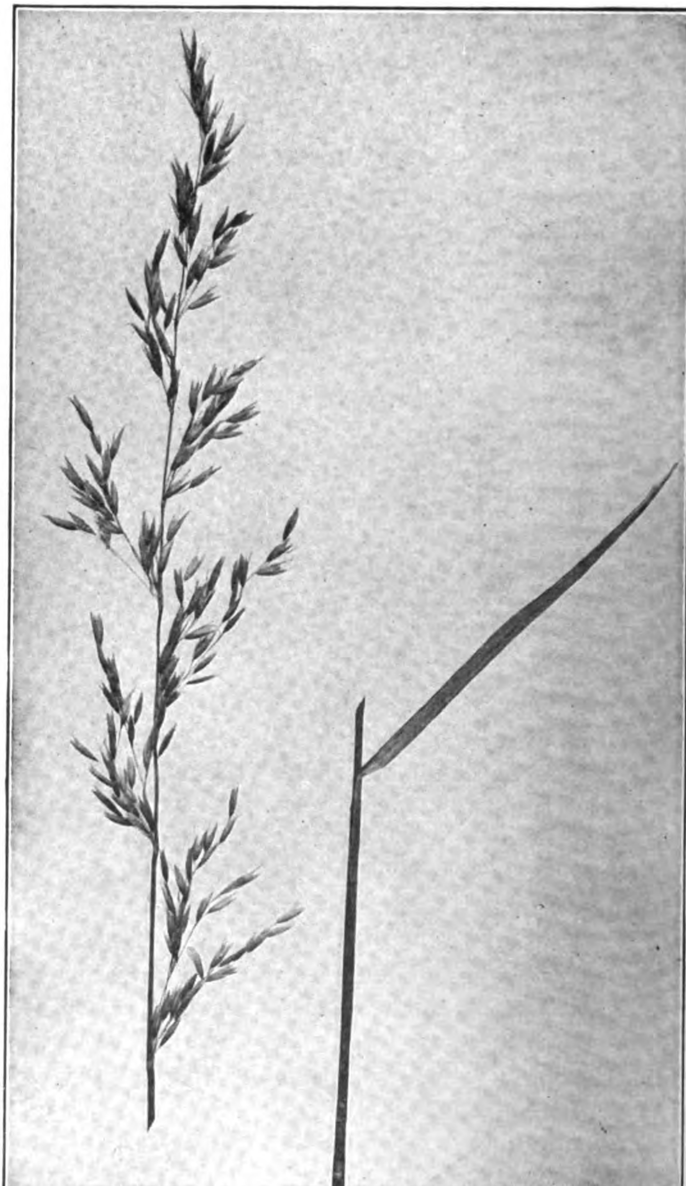
In the United States it has never gained a prominent position and is practically unknown in Ohio.

It is frequently recommended as a minor ingredient of pasture mixtures but it will hardly make headway in competition with blue grass, redtop, timothy and orchard grass. Used in mixtures of ten different grasses at the Cornell Station, it "has not been observed at all."

It is better adapted to rich, moist soils than to other types. Thirty pounds of seed per acre is needed, when seeded alone. The seed of perennial rye grass is very cheap.

Yield: In our tests of ten grasses, perennial rye stands lowest in yield of hay, the four year average being only 1.82 tons per acre.

It can hardly be recommended for Ohio conditions.



Tall oat grass

Perennial rye grass

ITALIAN RYE GRASS

Italian rye grass (*Lolium italicum*) is a biennial. Under some conditions it will perpetuate itself by reseeding, but it cannot be counted upon to do so.

It is a very rapid grower. Compared with the perennial rye grass, the Italian rye is of a lighter shade of green, grows more rapidly, is earlier, has coarser stems, and is taller. The seed may be distinguished from the fact that the Italian rye has a small beard, while the perennial does not.

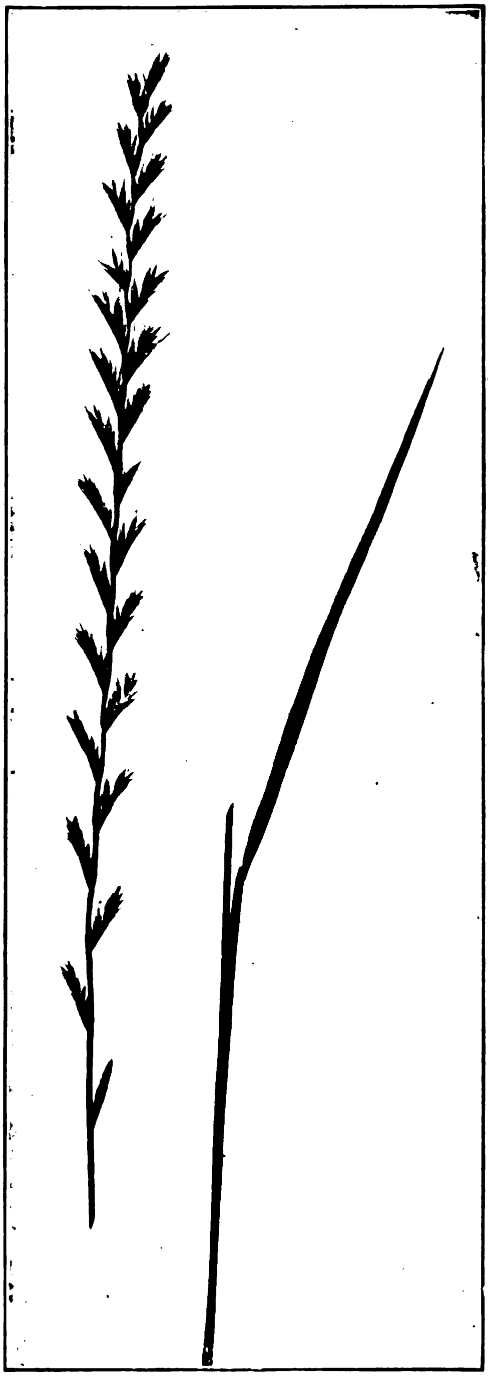
The Italian rye grass is not adapted to pasturing, as it is too short-lived. Its greatest success seems to be under irrigation. It is frequently used to seed lawns for the reason of the quick covering of green it furnishes, though it is of no value as a permanent lawn grass. For field conditions 35 pounds of seed per acre are required.

Yield: This Station has had it in its large plot tests but one season, when it gave a yield of 2.56 tons per acre, standing seventh among ten other grasses.

A FURTHER WORD ON PASTURES

In addition to what has been said about pastures under blue grass and other grasses, attention should be called to the desirability of mowing pastures over once during July or August. Not simply clipping a little here and there with a scythe, but a thorough going over with a mowing machine. In some pastures this will necessitate a great deal of grubbing and cleaning up, which in itself will mean more and better grass. This mowing prevents the weeds, which usually are not cropped back by the livestock, from taking moisture greatly needed by the grass, thereby weakening and gradually crowding the grass out. And, if the mowing be done at the proper time, it greatly reduces the future crop of weeds by the prevention of seeding, and also destroys many weeds outright by cutting them off at a critical stage. The mowing machine should be set to run moderately high. It will be found a very useful implement in pasture fields.

Furthermore, pastures should be systematically fed. In the absence of applications of manure or fertilizers, lands kept in permanent pasture may be expected to decline. The production and removal of bone, flesh, wool, milk, etc., can but reduce the stock of plant food in the soil. If the product of our pastures is to be increased, or even maintained, there must be a restoration of the plant food removed, as may be needed; particularly of the phosphorus, and frequently on the thinner soils, of nitrogen, potassium and lime. A dressing of stable manure is valuable, but seldom is it available. Usually it is necessary to resort to the use of commercial



Italian rye grass

fertilizers. Applications of 200 pounds of steamed bone and 30 to 40 pounds of muriate of potash per acre are helpful. Off the limestone, occasional dressings of fine ground limestone (1 to 2 tons per acre) may be expected to be needed. It will be better to let several months intervene, if possible, between the application of limestone and manure.

After treating as above suggested, a heavy spike-tooth harrow can often be used with profit, and also additional grass and clover seed.

Grass Mixtures—For ordinary conditions, the following mixture is suggested for an acre of ground:

Blue grass	10	pounds	Orchard grass	4	pounds
Timothy	6	"	Red clover	4	"
Redtop	6	"	Alsike clover	2	"

For use on rather wet soils, and especially off the limestone:

Redtop	12	pounds	Timothy	4	pounds
Blue grass	8	"	Alsike clover	4	"

THE COMPARATIVE COST OF SEEDING DIFFERENT GRASSES

In Table II is given the comparative cost of seeding an acre of land to the different grasses reported upon in this bulletin. The amount of seed indicated per acre is believed to be none too much for a good stand of plants, when using the best grades of commercial seed. The price of seed is from recent quotations from our best seed houses. The price varies with production. Timothy, for instance, is very high this season. It may be worth only one-half as much in twelve months.

It will be noted that the variation in the expense of seeding an acre to the different grasses is very great. This will have to be taken into consideration in determining their utility.

TABLE II. THE COST OF GRASS SEED PER ACRE

Name	Lbs. per acre	Cost per lb. cents	Cost per acre
Timothy	15	12	$ 1.80
Blue grass	25	22	5.50
Redtop	15	16	2.40
Orchard grass	30	18	5.40
Meadow fescue	30	25	7.50
Tall fescue	30	27	8.10
Brome grass	40	8	3.20
Tall oat grass	30	17	5.10
Perennial rye grass	30	6	1.80
Italian rye grass	35	6½	2.28

THE COMPARATIVE YIELD OF GRASSES

Seedings of nine different grasses were made in 1904. Size of plots, one-twentieth of an acre. Good stands were secured of all save brome grass. This plot was a failure. It bore a variety of grasses and weeds, but very little brome grass. Three successive crops of hay of the several grasses were harvested, when the plots were plowed up, cleaned, manured, limed and reseeded in 1909. In the reseeding, Italian rye grass was added.

The yield for the four harvests follow:

TABLE III. YIELD OF GRASSES

Name	Tons of hay per acre				
	1905	1906	1907	1910	4 yr. av.
Timothy	2.92	2.62	3.60	4.86	3.497
Blue grass	1.56	2.18	2.15	2.86	2.187
Redtop	2.75	2.96	2.22	3.34	2.817
Orchard grass	1.65	2.34	2.22	2.58	2.197
Meadow fescue	1.85	2.10	2.01	2.44	2.100
Tall fescue	1.95	2.18	2.59	3.02	2.435
Brome grass	1.45*	.....	2.74*	2.98	......
Tall oat grass	1.75	2.40	2.32	2.52	2.247
Perennial rye grass	1.72	1.70	2.11	1.76	1.822
Italian rye grass	......	......	......	2.56	......

*Almost everything in this except brome grass.

COMPOSITION OF OHIO GRASSES

The hay made from different grasses in 1910 was analyzed by the Department of Chemistry, to whom the writer acknowledges his indebtedness. Table IV gives the percentage composition and the pounds of the different constitutions per acre, using the four year average yield as the basis. The superiority of the old-time favorites is apparent.

TABLE IV. COMPOSITION OF OHIO GRASSES

Name	Pounds per hundred						Pounds per acre			
	Water	Ash	Protein	Fiber	N-free extract	Fat	Protein	Fiber	N-free extract	Fat
Timothy	2.93	5.00	6.38	37.90	45.17	2.62	446.2	2,650.8	3,159.2	183.2
Blue grass	6.22	5.62	10.12	32.27	43.51	2.26	442.6	1,411.5	1,903.1	98.9
Redtop	2.28	6.52	8.53	33.91	46.45	2.31	480.6	1,910.5	2,617.0	130.1
Orchard grass	5.58	6.98	7.81	35.45	41.88	2.30	343.2	1,557.7	1,840.2	101.1
Meadow fescue	4.96	6.70	8.97	34.94	42.11	2.32	376.7	1,467.5	1,768.6	97.4
Tall fescue	6.86	6.02	8.81	35.66	40.72	1.91	429.0	1,736.6	1,983.1	93.0
Brome grass	4.83	6.18	9.25	35.71	41.97	2.06	*	....	....	....
Tall oat grass	5.42	6.11	7.81	35.13	43.67	1.86	351.0	1,578.7	1,962.5	83.6
Perennial rye grass	5.75	7.29	7.59	32.89	44.67	1.81	276.6	1,198.5	1,627.8	66.0
Italian rye grass	4.79	7.03	6.59	32.70	46.90	1.99	*	....	....	.....

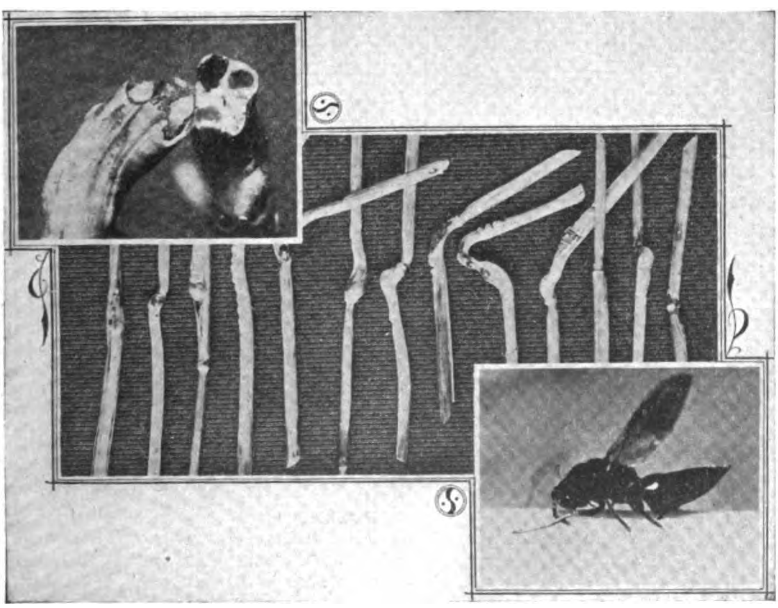
*Omitted in absence of four-year records.

THE WHEAT JOINT WORM

OHIO Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., FEBRUARY, 1911.

BULLETIN 226



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To CHAS. E. THORNE, *Director:*

SIR: I have the honor to transmit herewith and to recommend for publication as a Bulletin of the Experiment Station, the accompanying manuscript entitled "A study of Farm Equipment," which has been prepared by Mr. L. W. Ellis of the Office of Farm Management, Bureau of Plant Industry, United States Department of Agriculture.

This paper is based on a detailed study, made in cooperation with this office, of the equipment and the distribution of investment on a number of farms in this state. Few people realize the relationship of land, buildings, equipment stock, machinery, cropping systems and working capital to successful farming. This paper points out these relationships as they were found to exist on farms of various types in this state. It also includes an important study of machinery cost per year and per acre.

Respectfully,

L. H. GODDARD,
Chief of Department of Cooperation

Approved:
CHAS. E. THORNE,
Director.

CONTENTS

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 227 FEBRUARY 1911.

A STUDY OF FARM EQUIPMENT

By L. W. ELLIS

INTRODUCTION

Successful farm management presupposes a proper relation between the various factors of production. The process of adjusting land, labor and capital into harmonious relationship is consciously or unconsciously followed by all farmers. In the course of time the successful farmer reaches the point where productive area, live stock, cropping system, labor, equipment, and working capital are properly balanced and a profitable routine may be followed. Before that point is reached, however, many expensive mistakes are usually made, and perhaps none are more keenly felt than those arising from improper distribution of capital.

The study of farm equipment was undertaken for the purpose of determining from the study of successful farms the proper relationships that should exist between investments in land, improvements, livestock, machinery and tools.

This report presents the results of a study of equipment on a number of farms where conditions were unusually favorable for securing the desired information. The data and observations would undoubtedly have been more complete and satisfactory had a thorough preliminary analysis of the situation been possible in the light of later knowledge. They are presented, however, as secured, in order to illustrate by concrete example numerous problems that arise in this field of investigation. A portion of the data secured in these investigations has already been published*.

*Circular 98, of this Station, regarding "Minor Items of Farm Equipment". This will be sent free on application to the Ohio Experiment Station, Wooster, Ohio.

METHODS OF PROCEDURE

The work was done under the joint auspices of the Office of Farm Management, U. S. Department of Agriculture and the Ohio Experiment Station. During February and March, 1909, in connection with the annual inventories on the farms of about thirty-five statistical cooperators, a detailed study of the equipment was made in so far as it was possible to secure information from the proprietor or manager. Specially prepared forms were used in order to obtain full details. Previous field measurements of the various farms by Mr. H. C. George of the Experiment Station gave accurate data as to the size of each, the areas devoted to different purposes, the length and character of fences and certain other details. Measurements and sketches were made of the buildings, and numerous details as to their character and condition were noted. The extent, character, and cost of water supply and drainage systems were studied.

The usual inventory of livestock, machinery, tools and supplies was made to include many details in addition to mere values. Messrs. Abbot, Bugby, Elser and Lloyd of the staff of the Experiment Station assisted at various times in the field work, and Mr. C. A. Massaro of the Department of Cooperation assisted in the compilation of the data.

In the case of every farm studied, difficulty was encountered in securing all the details desired. Especially was this true in the matter of cost of permanent improvements, the installation of which usually antedated the tenure of the incumbent proprietor. The determination of the present value of real and personal property was also especially difficult, as a uniform basis could not be maintained for the reconciliation of exchange value with the value in use.

Previous to the work just mentioned, about twenty successful Ohio farms were visited by Mr. H. C. Thompson, of the Office of Farm Management, and less complete equipment studies made. Some data from this source are included in this report. A third source of data consists of circular letters dealing with corn and tillage machinery which were sent out in 1908 to a selected list of Ohio farmers. Over 100 carefully prepared reports of this character have been drawn upon for material.

CHARACTER OF FARMS STUDIED

The farms from which data were secured for this report are probably above the average in the character of the proprietors, methods and equipments, yet not necessarily examples of exceptionally successful management. They are well scattered over the

ıtate, as shown in Fig 1. Only those visited in 1909 were analyzed ıs to the chief enterprises conducted. For convenience, these have ɔeen numbered as in the various tables presented later. On 23 of :hese farms it was found possible to make a complete distribution ıf investment by enterprises, and it is with these that this report ıas chiefly to deal. Data from two of these are excluded from the .verages given later, one being a small truck farm and the other a ;eneral farm on which conditions had operated to reduce the equip- ɑent investment to an abnormally low figure. Figures from both re made available for comparison as well as those from a number of arms on which the analysis could not be completed.

Fig. 1. Showing location of farms studied

TABLE I. COMPARISON OF AVERAGE DATA FROM 21 OHIO FARMS WITH STATE AVERAGES FROM THE CENSUS OF 1900.

	State average			Average of 21 farms		
	Per farm	Per acre	Percent	Per farm	Per acre	Percent
Area in acres	88.5	......	......	165.88	.....	......
Total value of land, improvements, livestock and machinery	$4,333.	$48.96	100.00	$14,461.10	$87.17	100.00
Value of land, fences, drainage, water supply, etc	$2,953.	$33.37	68.16	$ 8,748.56	$52.72	60.48
Value of buildings	$ 793.	$ 8.96	18.30	$ 3,049.47	$18.38	21.08
Value of implements and machinery	$ 132.	$ 1.49	3.04	$ 773.92	$ 4.67	5.36
Value of livestock	$ 455.	$ 5.14	10.50	$ 1,889.15	$11.40	13.08
Percentage of improved land in farms*	78.5	......	......	80.9	......	......

*In the state average this includes all land regularly tilled or mowed, land pastured and cropped in rotation, land lying fallow, land in gardens, orchards, vineyards or nurseries, and land occupied by buildings. No instructions were given to census enumerators as to the disposition of public and private roads, all or part of which may be included in the farm areas covered by deeds.

In the average for the 21 farms, waste lands, roads and barn lots are classed together as non-productive. Pastures, tilled fields and orchards constitute 80.9 percent of the total area. See Table III for details of acreage.

The 21 farms represented in the tables showing average distribution of investment range from about 50 to 400 acres in size, averaging about 166. In this and other particulars they differ materially from the state averages as reported in the Twelfth Census (1900). According to the census report 32.4 percent of the farms of the state were between 50 and 100 acres and 24.3 per cent between 100 and 175 acres in size. Table I presents a comparison of the average of the 21 farms and that of the state as shown by the census. It will be remembered, however, that the census valuations are made on the basis of sale values. In taking the inventories, consideration was given to both this sale value, and the original cost of property less a reasonable depreciation charge based on its condition and length of time already in use in proportion to its expected total life. This will lessen the apparent difference between these farms and the average for the state.

Of the 21 farms six include dairying as the principal enterprise, one is devoted largely to feeding sheep, and two more place greater emphasis on the feeding of cattle than the average farm, but in no instance are the equipment and management those of a highly specialized type of farm. They represent, on the whole, the most common type of farm to be found in the state, with the exceptions previously noted. Concerning the farms visited by Mr. Thompson and those covered by circular letter, it may be said that they represent the general rather than any special type, and are probably better organized, equipped and managed than the average of all farms in the state. It is the equipment of this class rather than that of highly specialized farms or that of groups including both the best and poorest examples of farming that has been studied in the endeavor to establish logical relationships between the land, improvements, stock and machinery required for successful operation. The data hereinafter presented are conclusive only in so far as the farms studied are typical. It is held, however, that similar analyses of a large number of farms in any section would afford reliable averages from which the proper distribution of capital in equipment for a given farm could be predetermined with scientific accuracy.

DISTRIBUTION OF INVESTMENT

There are three distinct objects sought in this study of farm equipment: (1) The amount of equipment necessary and its first cost; (2) The inventory valuation at a given time; and (3) The equipment charge on farm operations, a portion of which is represented in the difference between the first cost and a succeeding

inventory valuation. The second phase will be discussed first, i. e., the present distribution of investment as shown by inventory. Land, Buildings, Fences, Drainage, Water Supply, Livestock, Machinery and Tools, and Produce and Supplies are regarded as the principal divisions of equipment. These classes are also divided among the enterprises. The enterprise, rather than the farm, was regarded as the unit.

LAND

In Table II is shown for 1909, the distribution of acreage by enterprises for the various farms. Under "General farm" is included areas in lots, lanes, waste spots, public roads and all other lands belonging to the farm which cannot properly be charged to one enterprise or a group of enterprises. "Household" includes dooryard and family garden, also the orchard where the latter is not at all a commercial proposition. Tenant yard, garden, etc., are charged to "Labor." "All stock" refers to all lots and fields devoted exclusively to livestock. Where pastured fields contained any considerable growth of trees, the judgment of the surveyor was relied upon for a division of the field into pasture and woodland. Temporary pastures are included under this head, hence the areas devoted to "All stock" and "All crops" would vary from year to year. Under "All crops" are included all tilled and mowed fields. On several farms, certain groves, considered as permanent, were maintained largely for the production of maple sugar or syrup, hence the occurrence of a "Sugar" enterprise. Under "Orchard" are included only fruit orchards largely commercial in nature. "Woodland" comprises not only natural tracts but those planted for the production of wood, posts, etc. The value given for the bare land represents as accurately as possible the value after all improvements are removed.

An examination of Table II shows that the mean acre valuation for 21 farms is $45.96. On farm No. 1 the acre valuation of bare land is $61.62. On farm No. 2 it is $19.53. These farms are both in the northeastern part of the State and are both dairy farms. No. 1 is a mile and a half from town on a stone pike, while No. 2 is five miles out on a dirt road. Part of the woodland in No. 1, but no distinct area, produces maple syrup in commercial quantities Farm No. 4, with an acre valuation of $31.15, and farms Nos. 8, 9, and 10, with respective acre valuations of $87.74, $65.99, and $71.00, are all level farms. No. 4 needs considerable drainage. Nos. 8, 9, and 10 are well equipped with tile drains. Also Nos. 8 and 10 show

a high percentage of land in crops, i. e., 74 percent and 84.2 percent respectively, as against a mean of 52.8 percent for the whole 21 farms. No. 25, with 91.9 percent of land in tilled crops and situated within a stone's throw from an interurban railway, shows a bare land valuation of $40.10 per acre. This farm, however, lacks tile drainage and is over-equipped with buildings as compared with other farms. (See Table III for data on Building Equipment.) No. 3, with an acre valuation of $41.44, has also a very expensive building equipment, and even when this equipment is placed at a very low figure compared with its cost, it leaves a low figure for bare land. No. 14, although the largest farm of all, with a total of 388.92 acres, has but 50.7 percent of the land in crops, the mean being 52.8 percent. It contains, however, a large acreage of productive bottom land, has a low building investment per acre, and has good roads to a shipping point, which gives the bare land an acre valuation of $60.00, as compared with the mean average of $45.96 for the 21 farms. Farms Nos. 20, 21, 22, and 23, with bare land valuations of $43.97, $22.26, $25.55, and $29.59, respectively, are all located in the hill section (southeastern part) of the state. No 20, with a valuation of $43.97, shows an unusually low area in waste and timber land for a hill farm and is connected with town by 6 miles of pike road. No. 23, with a valuation of $29.59, and with nearly the same size, distribution of acreage, and distance from railway station, is separated by 3 miles of hilly dirt road from the pike leading to town. No. 21, with a valuation of $22.26, has considerable waste and timber land, and No. 22, with a valuation of $25.55. has been wisely kept in pasture for the greater part, though a greater area in crops would have made it more attractive to a buyer. Nos. 12 to 17 inclusive ranging in bare land value from $43.90 on farm No. 15, to $64.89 on farm No. 17, are located in the large farm area of central and southwestern Ohio. Only one of this group falls below the average bare land valuation of $45.96. These farms are well equipped with buildings and are quite easily reached by pike roads from good towns. Most of them show a higher percentage of crop land than the mean of the whole number and are in a high state of productivity. No. 24, with a bare land valuation of $19.61, is located in a rougher section in southern Ohio, is under-equipped in buildings and is conservatively valued rather than otherwise.

From these examples the land values, due to good roads, good drainage, high crop areas, good topography, and adequate improvements can be plainly seen.

TABLE II. ACREAGES ON 23 FARMS DEVOTED TO VARIOUS ENTERPRISES, WITH THE AVERAGE AND PERCENTAGE OF THE TOTAL ON FARMS NOS. 1 TO 23 INCLUSIVE, AND THE VALUE OF THE LAND MINUS ALL IMPROVEMENTS

Farm No.	General farm	Household	Labor	All stock	All crops	Sugar	Orchard	Woodland	Total	Percent in crops	Value of bare land
1	.93	.88	....	56.43	35.86	......	......	22.10	116.20	30.8	$61.62
2	3 86	2.33	....	54.42	68.14	......	......	35.36	164.11	41.5	19.53
3	3.68	1.66	....	16.97	53.71	......	14.43	13.80	104.25	51.5	41.44
4	4.38	1.36	....	25.96	56.22	16.35	4.07	......	108.34	51.8	31.15
6	4.28	3.57	....	37.50	73.65	23.27	......	1.05	143.32	51.4	24.18
7	4.07	1.69	....	18.98	20.80	......	......	4.07	49.61	42.0	33.00
8	2.94	2.03	....	14.52	58.15	......	......	1.00	78.64	74.0	87.74
9	5.41	1.02	.35	31.93	82.96	......	......	26.00	147 67	56.1	65.99
10	5.44	1.34	....	5.00	84.19	......	......	4.03	100 00	84.2	71.00
12	1.83	2.20	....	28.34	104.60	......	......	20.00	156 97	66.7	50.14
13	4.93	3.63	....	33.02	140.76	......	......	15.91	198.25	71.0	46.55
14	8.98	3 67	....	122 60	197.00	......	......	56.67	388.92	50.7	60.00
15	4.83	3.26	....	67.75	128.85	......	......	15 13	219 82	58.6	43.90
16	3.35	1.62	....	11.84	116.42	......	......	39.29	172.52	67.5	45.97
17	10.38	2.65	.49	84.93	124.47	23.06	......	30.02	275.99	45.1	64.89
18	8.40	1.45	....	26.32	123.20	......	3.71	44.75	207.83	59.4	56.49
19	3.00	1.65	....	21.81	69 42	......	......	7.93	103.81	66.8	40.17
20	7.18	.50	....	84.31	84 56	......	.99	7.71	185.25	45.7	43.97
21	14.11	1.47	.73	62.44	68.58	......	4.79	76.50	228.62	30 0	22.26
22	3.33	1.46	....	103.84	31.17	......	2 44	13.76	156.00	19.9	25.55
23	10.31	3.36	....	67.66	77.30	......	10.49	8.15	177.27	43.5	29 59
Average of 21 farms	5.51	2.04	.08	46.50	85.71	2.98	1.95	21.11	165.88	(mean) 52.8	(mean) 45.96
Percent of total acreage	3.32	1.23	.05	28.01	51.68	1.80	1.18	12.73	100.00	....	......
24	3.85	1.56	....	47.00	79.23	......	......	23.04	148.38	48.2	19.61
25	.65	.23	....	......	9.97	......	......	......	10.85	91.9	40.10

PERMANENT IMPROVEMENTS

The appraisement of the real value of permanent improvements in this study was extremely difficult and must be accepted with due allowances. Wherever practicable, the basis for fixing values should be that expressed in the following question: "What is the value of this item as a part of the equipment of this farm, remembering that the sum of these values must equal the value set upon the farm as a whole?" Land values have increased in nearly every section, not through improvement of the land by farming, unfortunately, but through an advance in land as a raw material. We have no means of determining the present producing power of a given farm as compared with that at the outset, nor what its rate of appreciation or depreciation has been in this respect. It seems well established that where systematic steps have not been taken to prevent it, or to repair damage, there has been a steady depreciation in the productiveness of any given farm. The buildings and other improvements on such a farm may clearly have undergone a process of deterioration, yet the sale value of the farm may have been enhanced, not only by the rise in land value but by the increase in value of the raw materials from which improvements are constructed. Well planned improvements may add value to the farm above their cost of installation, and others may immediately represent the loss of a large part of their cost if measured by their effect on the farm value. Each farm, therefore, was studied as an individual problem, and is most interesting when considered in that light.

DRAINAGE

Tile drains are so intimately associated with the land that it may be impracticable to consider them separately. With the possible exception of cost of water supply, the outlay in tile drainage is the only one which can be depended upon to add its face value or more to the value of the bare land and continue to do so indefinitely. The drains occasionally become clogged and require cleaning but in this study they have been appraised at the full cost of installation. To attempt to appraise them accurately on the basis of their effect on the farm value would be impossible from the information at hand. No valuation has been placed on natural drainage channels considered aside from the land. The investment in artificial drainage systems has been attributed directly to the portions of the farm drained.

WATER SUPPLY

On many Ohio farms there are natural sources of water supply which, like natural drainage, can scarcely be valued apart from the land. Their value may not equal their cost, as in the case of streams which permanently render a considerable area unavailable

for cropping, or which subject fields and fences to damage from high water. On the other hand, the value of a continuous supply of pure water in a convenient place, without expense or labor, cannot be estimated by comparing it with the cost of installing artificial water systems. The latter may represent several failures before a satisfactory supply is obtained, and will surely represent a continual expense for labor and maintenance. In distributing the investment for the purposes of this study, only the cost of installing the water system has been considered, less a fair amount for depreciation of pumps, tanks, windmills, etc. This total investment in water system has been divided as accurately as possible among the various enterprises on the basis of use. This naturally places the heaviest charges on the household and those classes of livestock which do not have access to natural sources in the fields.

FENCES

Fences well planned and constructed undoubtedly add at first more than their cost to the value of farms, yet if not well located they may prove a handicap to the most profitable cropping systems. They are subject to quite rapid deterioration, involving considerable attention and expense, hence over-equipment in fences may tend to reduce land values.

Certain phases of the fence question were studied in detail and will be discussed later, but in ascertaining the investment in fences the first cost and the condition at the date of inventory were the only points considered. The cost of construction was difficult to obtain, owing to the fact that practically all fences are built by farm labor, and standard costs per rod have not been established as has been done, for instance, for the digging of ditches for tile drains, which is often paid for on a unit basis. The price of posts varies widely in different localities and has generally advanced since the building of the older fences.

The value of fences, therefore, was based largely on the cost of replacing them, less a fair percentage for depreciation. Worm rail fences constitute a large proportion of the total on many Ohio farms. When built, the value of the material was practically disregarded. Labor costs were very low as compared with the present rates. It would be impossible to replace these fences except at a prohibitive cost, yet in real value to the farm they are no higher than modern fences. Many are in an excellent state of preservation, yet occupy enough additional ground to offset any advantages they may have over wire fences. As an expedient they have been valued at a figure approximating the labor cost of building. All fences were charged to "General farm", only the farm's share of division fences being included, of course.

BUILDINGS

any buildings found on the farms studied are from 40 to 75 old and of a type of construction not commonly used at present ıme being composed of large, hewn timbers. Much of the material has been cut and sawed on the farm, the value of the r at the time being very low as compared with present prices. buildings, as a rule, are still in such condition as to be cap- f long service without excessive repairs. The first cost of ial and labor was low, yet on the present basis it would nost out of the question to duplicate the buildings.

follows, then, that neither the cost of the buildings nor the f replacing these structures can be relied upon absolutely in ising their value. As previously stated, the cost of the more rn buildings is not a true indication of their value to the farm, ısurance figures are quite largely based on their condition and ost of replacing them. A comparison of the sale values of land ut buildings and land with buildings, all in the same neighbor- and of equal productiveness, shows that the difference in favor latter is almost without exception greatly insufficient to equip nimproved land without buildings with those structures which bsolutely necessary to the conduct of an independent farming prise. The real value of farm buildings as a part of the total tment is, therefore, very difficult to ascertain, and depends ly upon the point of view.

n this study the building values are a compromise between the of equipping the farm with similar structures, less a proper ınt for depreciation, and the sale value of the buildings as sug- ed by comparing the values of land with and without buildings. value shown for the bare land, therefore, is reduced somewhat by method, possibly to as great an extent as it was elevated by the ıod of appraising the fence, drainage and water supply systems.

It can safely be said that buildings represent not only the most nsive class of farm equipment, but the least negotiable. ving out household buildings, the remainder on the farms lied shows a much greater variation in investment per acre than other class of equipment and greater variation in percentage of total investment than land, water supply, livestock or machinery. ces and artificial drainage and water systems may often be ensed with wholly or to a great extent, hence are scarcely ıparable with land, buildings, livestock and machinery as regards relative investment.

One of the most important phases of a study of farm equipment hat of determining the relation that should exist between build- s and the farm enterprises, in order to reduce the wide variation

in investment per acre in buildings designed for the same purposes. Prior to a study of the cost and construction of buildings, there should be established standard space units, to be used in determining the actual building requirements of the farm for the storage of products and machinery, the housing of livestock and the transaction of the farm affairs. In this study, buildings were investigated from that standpoint, but insufficient data were secured to allow of generalizations.

For purposes outside of this study it became desirable to make a division of building investment by enterprises. As the floor and cubic space devoted to each enterprise had been calculated for the various buildings; a division on the basis of cubic space was worked out, and is presented later in tables and discussions.

It will be at once apparent that a division of space on the basis of cubic feet devoted to various enterprises in barns, for instance, is open to serious criticism. This subjects such products as hay, straw, etc., stored in mows, to greater building charges than horses and cattle, for which greater expense is incurred in constructing stalls, mangers, floors, etc. In order to correct this error, additional study of the cost of construction of the various portions of the buildings would be necessary, and the need for this did not occur in time to include it in the scope of this study.

Factors for the relative cost of various portions of farm buildings of ordinary construction could no doubt be worked out, by means of which the cubic space devoted to any enterprise could be made the basis for an equitable division of the total value. Some method is desirable, as it is incorrect to charge livestock enterprises with the investment in portions of the buildings devoted to other enterprises. Animals may be fed grain in the barn for a short time each day and pastured outside, while both hay and grain may be stored in the barn continuously for market. A storage charge, in the latter case, should unquestionably be added to the cost of production. It is only logical to base the unit charge on the amount of the commodities stored, taken in connection with the total annual cost of that part of the building designed exclusively for storing products. A unit storage charge based on cubic space would place on the proper classes of livestock the burden of the large amount of storage space required for roughage. A division of the entire building charge on the basis of the number of 1,000 pound-shead of stock sheltered, or on the floor space occupied, might be unjust to the hog enterprise, for which a comparatively small space is required for storage of feed. A tool room, workshop, driveway, or other space may be used for storing tools, wagons and machinery, for storing and

preparing seed, and for other purposes which are obviously not associated with livestock enterprises. Conceding the partial inaccuracy of a division of building values on the basis of cubic space occupied, it is contended that even this method results in a distribution of building charge more nearly correct than one based on the number, size or value of livestock alone. Considering the importance of the building equipment, it is unfortunate that so little investigation has been conducted with a view to discovering the fundamental principles involved in the economical planning of farm buildings.

PERSONAL PROPERTY

All personal property has been valued with due consideration for both exchange value and value in use. Marketable livestock and products were invoiced at the prevailing prices. Work animals and machinery, however, have a value to the farmer not necessarily the same as that which would prevail either in public or private sales. This fact has been taken into consideration, hence the values presented for the work horses, mules and machinery are usually higher than sale values. The sale values could, at best, have been approximated. All products of the farm, all feed, seed, building material, fuel and supplies of any kind held in storage for sale or for the use of the farm (not household) business, were inventoried at actual values so far as they could be determined.

Table III shows the total investment in different classes of equipment for the various farms, distributed as explained in the preceding pages. The area, 342 acres, given for Farm No. 5, was not verified by the surveyor from the Ohio Agricultural Experiment Station. The proprietor of Farm No. 11 could not give the extent nor value of the tile drains; hence this value is included in that of the land. A very slight quantity of tile is included in the land value for farm No. 16. The total investment is shown for the different farms to vary from $35.21 to $166.30 per acre and this is brought out even more clearly by Table IV, which reduces all the investment to the acre basis. The variation in total value of household buildings ($310 to $6,110) is interesting from the fact that the investment in this direction is usually not based on the absolute needs of the farm. The variation in the amount of produce and supplies on hand ($10.10 to $1,942.15) is due partially to the fact that the work of taking the inventories lasted over a period of six weeks, during which time of course, the consumption of feed continued. For comparable data, all inventories, particularly of supplies, should be taken on the same date. In this study, except as affecting the percentages of the total investment shown later, the amount of supplies on hand is unimportant.

TABLE III. TOTAL INVESTMENT IN THE DIFFERENT CLASSES OF FARM EQUIPMENT ON 25 OHIO FARMS

Farm No.	Acres	Land	Farm buildings	Household buildings	Fences	Drainage	Water supply	Livestock	Machinery etc.	Produce, supplies, etc.	Total	Acre investment
1	116.20	$ 7,160	$1,025	$1,500	$ 245	$ 45	$ 50	$1,265.00	$ 667.50	$ 220.85	$12,178.33	104.81
2	164.11	3,205	1,000	800	250	85	60	1,651.20	623.95	520.22	8,195.37	49.94
3	104.25	4,320	2,800	2,500	455	250	100	1,363.75	664.25	671.95	13,124.95	125.90
4	108.34	3,375	1,405	700	320	30	170	1,336.25	682.34	329.02	8,347.61	77.05
5	342.00	9,570	6,250	6,110	1,255	2,795	700	3,549.00	1,065.80	1,942.15	33,236.95	97.18
6	143.32	3,465	900	900	565	......	170	1,767.68	1,086.68	323.50	9,177.86	64.04
7	49.61	1,637	440	310	223	60	80	959.75	630.38	131.65	4,471.78	90.14
8	78.64	6,900	1,000	1,879	400	1,100	250	654.40	547.05	351.45	13,081.90	166.30
9	147.67	9,945	1,490	2,060	95	500	110	1,804.00	1,267.10	1,297.23	18,369.33	124.32
10	100.00	7,100	1,215	1,525	590	1,770	300	1,496.50	645.10	274.75	14,916.35	149.17
11	186.71	15,001	1,525	1,225	630	......	290	2,942.00	1,313.34	1,203.52	24,129.86	129.24
12	156.97	7,870	3,830	1,800	395	1,830	275	2,516.75	788.75	653.00	19,958.50	127.15
13	198.25	9,228	2,260	2,850	1,130	680	350	2,438.55	980.25	1,390.60	21,297.40	107.43
14	388.92	23,335	1,720	1,585	890	345	157	3,936.70	1,115.45	1,478.40	34,562.55	88.87
15	219.82	9,650	930	900	900	135	125	1,975.65	679.90	609.55	15,805.10	71.90
16	172.52	7,930	825	720	625	......	100	1,286.50	679.40	527.70	12,693.60	73.58
17	275.99	17,910	1,225	2,900	1,070	220	135	3,450.00	1,024.00	275.25	28,209.25	102.21
18	207.83	11,740	3,277	1,843	315	345	150	1,917.78	1,054.67	1,009.75	21,642.20	104.14
19	103.81	4,170	2,370	1,020	400	300	70	2,550.00	731.55	926.90	12,538.45	80.22
20	185.25	8,145	2,235	1,150	660	......	50	2,883.75	556.10	817.80	16,497.65	89.05
21	228.62	5,090	724	1,726	700	......	550	1,362.50	807.90	369.95	11,330.35	49.56
22	156.00	3,985	1,060	1,500	365	......	70	1,281.50	346.60	285.25	8,893.35	57.01
23	177.27	5,245	580	1,570	720	......	285	1,774.00	683.10	804.70	11,661.80	65.78
24	148.38	2,910	100	800	250	......	20	860.00	173.20	115.45	5,228.65	35.21
25	10.85	435	350	500	45	......	20	238.15	156.20	10.10	1,754.45	124.43

: IV shows the acre investment in the various classes of
.t for 30 farms. With the exception of Nos. 5 and 11, all
to and including No. 23 have also been included in tables
the division of investment by enterprises, hence they are
1 in this table from those which are less complete. Nos. 5,
.d 30 had not been surveyed by the Station surveyor up to
these data were compiled, hence the acreages are only ap-
te. In several cases, the value of improvements was not
d from that of the land for want of sufficient information.
: land value in these cases includes all permanent improve-
ot otherwise shown. These incomplete data are presented
parison with the mean and average of the 21 farms. While
ι for Nos. 24 and 25 were complete, they were excluded from
ιmary as not representative, the former because of the ex-
r low investment and the latter because of the low acreage.

:lose study of the table will reveal striking differences in the
nent per acre for different purposes. As a basis for com-
the individual farms, the mean and the average of data from
ns are both included. The mean is obtained by adding to-
the average figures per acre for the different farms and
ıg by 21, while the average is secured by taking the total in-
ent for all the farms and dividing by the total acreage of all
rms. The mean, then, is an average having the farm as a
while the average regards the acre as the unit. These two
: vary widely, and the fact that they do not adds to the value of
.ble. In this study of farms, the mean is regarded as the more
estive, since it takes into account the effect of the size of the
upon the acre investment.

The range in investment per acre farm in buildings is seen to
om 67 cents on farm No. 24, where a very old barn and several
lly old sheds, etc., constituted the building equipment, to
!5 for farm No. 25, where the value of a small barn and poultry
e is divided by a small acreage. The investment varies with
condition and number of buildings, but the number and cost do
vary with the acreage.

Farms Nos. 13 to 17 are similar in character and location, yet
building equipment on farm No. 13 is $11.35 per acre, while on
s. 14 to 17, inclusive, the valuation does not reach $5 per acre on
farm. This is due to the fact that Farm No. 13 is really com-
ed of three farms formerly separate. On the other hand, farms
s. 3, 5, 12, 18, 19, and 28, ranging in size from 103 to 342 acres,
ow an investment in farm buildings of $15.78 to $26.85 per acre,
ile Nos. 7, 8, 10, and 30, varying in size from 49.61 to 100 acres,
ve an investment in farm buildings of but $6.33 to $12.70 per acre.

TABLE IV. AVERAGE INVESTMENT PER ACRE IN LAND, IMPROVEMENTS AND PERSONAL FARM PROPERTY ON EACH OF 30 OHIO FARMS, WITH THE MEAN AND THE AVERAGE INVESTMENT PER ACRE FOR A GROUP OF 21 OF THESE FARMS

Farm No.	Acres	Land	Farm buildings	Household buildings	Fences	Drainage	Water supply	Livestock	Machinery, etc.	Produce, supplies, etc.
1	116.20	$61.62	$ 8.92	$12.91	$2.11	$ .39	$ .43	$10.89	$ 5.74	$1 90
2	164.11	19.53	6.09	4.88	1.52	.52	.37	10.06	3.80	3.17
3	104.25	41.44	26.85	23.98	4.37	2.40	.96	13.08	6.37	6.45
4	108.34	31.15	12.96	6.46	2.96	.28	1.57	12.33	6.30	3.04
6	143.32	24.18	6.29	6.29	3.94	....	1.19	12.32	7.58	2.26
7	49.61	33.00	8.87	6.25	4.50	1.21	1.61	19.35	12.70	2.65
8	78.64	87.74	12.70	23.90	5.08	13.98	3.17	8.31	6.94	4.48
9	147.67	65.99	10.08	13.93	.64	3.38	.74	12.20	8.56	8.80
10	100.00	71.00	12.15	15.25	5.90	17.70	3.00	14.97	6.45	2.75
12	156.97	50.14	24.40	11.46	2.52	11.66	1.75	16.02	5.03	4.17
13	198.25	46.55	11.35	14.38	5.69	3.43	1.77	12.30	4.95	7.01
14	388.92	60.00	4.43	4.07	2.29	.89	.40	10.11	2.87	3.80
15	219.82	43.90	4.23	4.09	3.65	.61	.57	8.99	3.09	2.77
16	172.52	45.97	4.78	4.17	3.62	....	.58	7.46	3.94	3.06
17	275.99	64.89	4.44	10.51	3.88	.79	.49	12.50	3.71	1.00
18	207.83	56.49	15.78	8.86	1.52	1.66	.72	9.24	5.02	4.85
19	103.81	40.17	22.81	9.81	3.86	2.89	.68	24.58	7.05	8.93
20	185.25	43.97	12.07	6.20	3.56	....	.27	15.57	3.00	4.41
21	228.62	22.26	3.16	7.55	3.06	....	2.40	5.95	3.54	1.64
22	156.00	25.55	6.79	9.62	2.35	....	.44	8.21	2.22	1.83
23	177.27	29.59	3.27	8.86	4.06	....	1.60	10.01	3.85	4.54
Mean of 21 farms	165.88	45.96	10.59	10.16	3.39	2.94	1.18	12.12	5.36	3.97
Average of 21 farms	165.88	46.25	9.27	9.11	3.22	2.21	1.04	11.40	4.67	3.81
State average (Cen.1900)	88.50	33.37	8.96	......	....	....	....	5.14	1.49	....
5	342.00	27.98	18.29	17.87	3.66	8.17	2.04	10.38	3.14	5.68
11	186.71	80.34	8.17	6.56	3.38	..	1.55	15.76	7.06	6.44
26	166.86	65.00	......	......	....	...	....	7.53	4.51	1.38
27	180.00	69.98	9.30	10.16	....	....	....	11.96	3.60	2.45
28	504.00	70.00	17.11	6.55	....	...	...	24.12	7.56	4.73
29	156.00	76.92	7.20	15.88	....	..	....	9.30	7.19	4.02
24	148.38	19.61	.67	5.39	1.68	....	.14	5.78	1.17	.78
25	10.85	40.10	32.25	46.00	4 15	...	1.84	21.96	14.39	.98
30	79.00	48.04	6.33	31.61	1.40	....	1.14	18.20	6.13	2.84

In household buildings there is a variation of from $4.07 to $46.09 per acre. Taking the 21 farms as a whole, there is practically the same investment in farm and household buildings, viz., $10.59 and $10.16 respectively, but among the 30 farms there are wide extremes represented. Farms Nos. 4, 12, 18, 19, 20, and 28 show from two to three times as great an acre investment ($12.07 to $24.40) in farm buildings as in household building ($6.20 to $11.40) while on Farms Nos. 8, 21, 23, 24, 29, and 30 the investment in household buildings ($5.39 to $31.64) is from two to five times as great as in farm buildings($3.16 to $12.70 per acre).

No particular need is apparent for such a wide variation in practice, and on a number of the most successful farms the investment in household and farm buildings is about equal. On Farm No. 24 with a farm building investment of $0.67 per acre and household building investment of $5.39 per acre, a new barn was to be erected within a year or two which would bring about nearly the same relative condition as exists on Farm No. 18, on which a $3,000 barn had just been completed and on which the farm and household building investments were $15.78 and $8.86 per acre respectively. The owner of Farm No. 30 moved from the city only a few years ago and invested the greater part of his ready capital in remodeling the dwelling. His percentage of total investment represented by the household building is much higher than that of any other farm except the small truck and poultry farm, No. 25, and even slightly exceeds the figure for that one. He spoke of the lack of certain essential machinery which was directly due to the excessive outlay in household buildings and conveniences.

New buildings for either household or farm use tend of course to vary the relation, as does also the presence of tenant houses, which are classed with household buildings, yet the few farms studied would indicate that the investment in buildings for both purposes should be approximately equal for farms of the general class.

A large part of Farm No. 9, with an investment for fencing of only 64 cents per acre, is unfenced, and on several others a large extent of rail fence accounts for a low investment per acre. Attention is called to Farms Nos. 7 and 8 with fencing investments of $4.50 and $5.08 per acre respectively, on which the proportion of road fence is particularly large. No. 13 has considerable road fence, but the high investment ($5.69 per acre) is largely due to the recent construction of woven wire fences and the generally good condition of those previously installed.

The acre investment in tile drainage and water supply depends largely upon the natural advantages of the farm. The extremes are, for drainage, 28 cents on Farm No. 4, and $17.70 on Farm

No. 10, the average being $2.21. The extremes for water supply are 37 cents on Farm No. 2, and $3.17 on Farm No. 8, with average of $1.04 for the 21 farms. Farms Nos. 8 and 10 have a high investment in all improvements and are the two highest in the amount invested in tile drainage, $13.98 and $17.70 per acre respectively, yet they show the highest bare land values, $87.74 and $71.00 per acre respectively. Both are connected with town by good stone roads, but the thorough drainage undoubtedly is a large factor in maintaining the value of the land.

The small acreage of Farms Nos. 7 and 25, 49.61 and 10.85 respectively, make the acre investment in water systems large, even though the systems are not extensive. Farms. Nos. 8, 21, and 23 with an acre valuation for water supply of $3.17, $2.40 and $1.60 respectively, have more or less extensive water conveniences in the dwellings. Nos. 21 and 23 with investments of $2.40 and $1.60 per acre respectively for water, are to be contrasted with Nos. 18, 19, 20, and 22 with the respective valuations of 72 cents, 68 cents, 27 cents, and 44 cents, which are also in what is known as the hill section, hence able to easily obtain water from springs, but have not extended the water conveniences to the dwellings. Gasoline engines used only for pumping add to the investment on Farms Nos. 10, 12, and 13 with the acre valuation for water supply of $3.00, $1.75, and $1.77 per acre respectively.

The livestock inventory, like that of produce, supplies, etc., should be taken on the same date for all farms in order to be comparable. This is brought out strikingly by the case of Farm No. 12. The inventory in 1908 showed $1,700 worth of steers on hand, or nearly $11 per acre for this class of stock alone. Several days previous to the 1909 inventory, 39 head were sold, hence this farm, which is usually heavily stocked with cattle, shows a lower acre investment ($16.02) than its average for the year. The inventory of livestock, even if taken on the same date each year for all farms would not show the average investment accurately, as on some farms feeding stock are purchased, fed and marketed between succeeding dates of inventory. This would entail the investment of a considerable amount of capital for the greater part of the year which would not be apparent in a study of inventories. The study of investment in live stock can best be made in connection with Table VIII, which shows the relative importance of the various livestock enterprises.

With the exception of Farm No. 22 (acre valuation $2.22) for which much of the machinery was borrowed, No. 24 (acre valuation $1.17), for which it was generally bought second hand, and Nos. 7 and 25, with valuation of $12.70 and 14.39, which are low in acreage,

the acre investment in machinery, wagons, harness, tools, etc., ranges within comparatively narrow limits, this being from $2.87 on Farm No. 13 to $7.56 on Farm No. 28. With the exception of Nos. 22, 24, 25, and 28 the total machinery investment per farm is seen by reference to Table III to vary only about 136 per cent, as compared for instance, to 1,275 percent for the total value of farm buildings and 835 percent for household buildings. Two large farms, Nos. 5 and 14, containing 342 and 388.92 acres respectively, show low acre investments in machinery, i. e., $3.14 and $2.87 respectively, while the largest Farm No. 28, containing 504 acres, ranks among the highest, showing an acre investment of $7.56 and indicating over-equipment.

TABLE V. TOTAL AND PERCENTAGE OF TOTAL INVESTMENT IN REAL AND PERSONAL PROPERTY FOR EACH OF 30 OHIO FARMS, WITH THE MEAN AND AVERAGE FOR 21 OF THESE FARMS

Farm No.	Acres	Real Estate		Personal property		Total investment per acre
		Total	Percent	Total	Percent	
1	116.20	$ 86.28	82.30	$18 50	17.70	$104.81
2	164.11	32.91	65.90	17.03	34 10	49.94
3	104.25	100 00	79.40	25 90	20.00	125.90
4	108.34	55.38	71.80	21.67	28.20	77.05
6	143.32	41.88	65.70	22.16	34.60	64.04
7	49 61	55.44	61.50	34.70	38.50	90.14
8	78 64	146.57	88 10	19 73	11.90	166.30
9	147.67	94.76	76.20	29.56	23.80	124.32
10	100.00	125.00	83.70	24.17	16.30	149.17
12	156.97	101.93	80.20	25.22	19.80	127.15
13	198.25	83.17	77 40	24.26	22.60	107.43
14	388.92	72.09	81.10	16.78	18.90	88.87
15	219.82	57.05	79.40	14.85	20 60	71.90
16	172.52	59.12	80.30	14.46	19.70	73.58
17	275.99	85 00	83.30	17.21	16 70	102.21
18	207.83	85.03	81.60	19.11	18.40	104.14
19	103.81	80.22	66.40	40 65	33 60	120.78
20	185.25	66.07	74.20	22.98	25.80	89.05
21	228.62	38.43	77 50	11.13	22.50	49.56
22	156.00	44.75	78.50	12.26	21.50	57.01
23	177.27	47.38	72.00	18.40	28.00	65.78
Mean of 21 farms	165.88	74.22	77.60	21.45	22.40	95.67
Average of 21 farms	165.88	72.10	78.14	18 88	21.86	90.98
State average (Census 1900)	88.50	42.33	86.50	6.63	13.50	48.96
5	342.00	78.01	80.30	19.17	19.70	97.18
11	186.71	100.00	77.40	29.24	22 60	129.24
26	156.86	65.00	82 90	13.42	17.10	78.42
27	180.00	90.00	83.30	18 00	16.70	108.00
28	504.00	93.66	72.00	36.41	28.00	130.07
29	156.00	100.00	83.00	20.51	17.00	120.51
24	148.38	27.48	78.00	7.73	22.00	35.21
25	10.85	124.43	77.00	37.27	23 00	161.70
30	79.00	88.61	80.00	22.17	20.00	110.78

The total and percentage of investment per acre in real and personal property is given in Table V, together with the mean and average for the 21 farms. The odd cents shown in the values of the real estate are due to the fractional parts of an acre in the farm areas, these usually being disregarded by the farm owners. The land with improvements is seen to range from $27.48 to $146.57 per acre, though nearly all farms are valued considerably higher than the State average as shown by the twelfth census. viz., $42.33 per

acre. The amount of personal property per acre, \$7.73 to \$40.65, is higher than the State average, \$6.63, in every case. It is to be remembered, however, that for comparison the value of produce, etc., is to be deducted from that of the personal property shown, the census values including only livestock and machinery. Excluding produce, etc., the average of the 21 farms shows 81.4 percent of the total farm value in real estate, and 18.6 percent in personal property as compared with 86.5 percent and13.5 percent, respectively, for the State. The greater value of personal property on these farms argues the correctness of the statement previously made that the farms under consideration are more successful than the average.

Including produce, etc., a mean of the 30 farms shows 77.34 percent of the total inventory value to be due to land and improvements. The mean of the 21 shows 77.6 percent in real estate and the average, 78.14 percent. Seventeen out of 30 farms range between 77 percent and 83 percent in real estate, these having a mean of 79.8 percent. These figures should serve as an indication of approximately the proper division of equipment capital on farms of this class, the cash and other assets, of course, not being considered in this study.

The percentage of the total investment represented by each class of equipment is given in Table VI. The uniformity in the percentage of value in land on Farms Nos. 14 to 17, viz., 67.52, 61.10, 62.46, and 63.49, respectively, and Nos. 20 to 23, viz., 49.36, 44.90, 44.80, and 45.00, respectively, is interesting. The former are large level farms in the southwestern quarter of the state and the latter are large hill farms in the southeastern quarter. The influence of size of farm is to be seen in Farms Nos. 7 and 25, and of large building equipment on several others already noted.

The average land value for the state should be compared with the total for land and all improvements except buildings on the 21 farms. The mean of the 21 farms shows 55.9 percent and the average 57.9 percent in land, fences, drainage, and water supply as compared to 68.1 percent for the State. The mean shows 21.7 percent and the average 20.2 percent in all buildings as against 18.4 percent for the State. Both percentages for the State would be lowered if produce, etc., had been included in the census. The percentage invested in fences varies even more widely than the acre investment, while the percentages in drainage and water supply usually vary with the natural features of the farm. Farms Nos. 5, 8, 10, and 12 with percentages of 8.41, 8.39, 11.27, and 9.18 respectively in drainage, have been tile drained over the greater part of their areas. A large part of the investment in water supply on Farm No. 21 is chargeable to household.

TABLE VI. THE PERCENTAGE OF THE TOTAL INVESTMENT REPRESENTED BY EACH CLASS OF EQUIPMENT ON 30 OHIO FARMS, WITH MEAN AND AVERAGE PERCENTAGES ON 21 FARMS

Farm No.	Acres	Land	Farm buildings	Household buildings	Fences	Drainage	Water supply	Livestock	Machinery, etc	Produce, supplies, etc.
1	116.20	58.79	8.42	12.31	2.01	.37	.41	10.39	5.48	1.82
2	164.11	39.12	12.20	9.74	3.05	1.04	.73	20.16	7.62	6.35
3	104.25	32.90	21.35	19.05	3.46	1.91	.76	10.39	5.06	5.12
4	108.34	40.42	16.64	8.29	3.84	.36	2.04	16.01	8.17	3.94
6	143.32	37.74	9.78	9.78	6.25	....	1.85	19.25	11.82	3.51
7	49.61	36.60	9.85	6.93	4.99	1.34	1.79	21.46	14.10	2.94
8	78.64	52.72	7.64	14.36	3.05	8.39	1.90	5.00	4.17	2.77
9	147.67	53.06	8.11	11.21	.52	2.72	.60	9.82	6.89	7.07
10	100.00	47.60	8.15	10.23	3.95	11.87	2.01	10.03	4.32	1.84
12	156.97	39.42	19.18	9.02	1.98	9.18	1.38	12.60	3.96	3.28
13	198.25	43.35	10.55	13.39	5.30	3.20	1.64	11.44	4.60	6.53
14	388.92	67.52	4.97	4.58	2.58	1.00	.45	11.40	3.22	4.28
15	219.82	61.10	5.89	5.70	5.06	.80	.79	12.50	4.30	3.86
16	172.52	62.46	6.50	5.67	4.95	....	.79	10.12	5.35	4.16
17	275.99	63.49	4.34	10.29	3.80	.78	.48	12.23	3.62	.97
18	207.83	54.24	15.14	8.51	1.46	1.59	.69	8.86	4.84	4.67
19	103.81	33.20	18.90	8.10	3.20	2.40	.60	20.30	5.90	7.40
20	185.25	49.36	13.55	6.97	4.00	....	.30	17.48	3.37	4.97
21	228.62	44.90	6.38	15.22	6.20	....	4.90	12.00	7.10	3.30
22	156.00	44.80	11.91	16.89	4.10	....	.80	14.40	3.90	3.20
23	177.27	45.00	4.97	13.46	6.18	....	2.42	15.21	5.86	6.90
Mean of 21 farms	165.88	48.04	11.08	10.61	3.54	3.07	1.23	12.68	5.60	4.15
Average of 21 farms	165.88	50.82	10.20	10.01	3.54	2.43	1.14	12.54	5.13	4.19
State Av. (Census 1900)	88.50	68.14	18.36	......	....	....	....	10.48	3.02	....
5	342.00	28.80	18.80	8.39	3.78	8.41	2.10	10.68	3.20	5.84
11	186.71	62.15	6.32	5.08	2.61	..	1.20	12.20	5.45	4.99
26	156.86	82.90	......	......	....	....	....	9.60	5.74	1.76
27	180.00	65.35	8.62	9.38	....	....	....	11.04	3.34	2.27
28	504.00	53.80	13.16	5.04	....	....	....	18.60	5.80	3.60
29	156.00	63.80	6.00	13.20	....	....	....	7.72	5.96	3.32
24	148.38	55.65	1.91	17.22	4.78	....	.38	16.45	3.31	2.21
25	10.85	24.79	19.95	28.50	2.56	....	1.14	13.58	8.90	....
30	79.00	43.38	5.71	28.56	1.31	....	1.03	11.92	5.53	....

The percentage invested in livestock is within the limits of 10 and 20 percent, except in a very few cases. On Farm No. 8, with a livestock investment of 5 percent, there are a low acre investment in livestock ($8.31 as against an average of $11.40) and a high land value ($87.74 as against an average of $46.25) to explain the low percentage. The farm is owned by a man who has limited his farming operations with advancing age. The percentages invested in livestock and machinery as shown by the inventories are lower than they would be on a basis strictly comparable with the State average, as the 4 or more percent in produce, etc., is included in this study and not in the census data. The average percentages for the 21 farms, with the last item omitted, would be as follows: Land and all improvements except buildings, 60.4; buildings, 21.1; livestock, 13.1; machinery, 5.4. The values placed on livestock and machinery were probably on a higher basis in these inventories than census valuations, and all prices were undoubtedly higher than in 1900, hence the comparison with the State averages is of less value than would at first appear. Farm No. 6, with a percentage of 11.82 in machinery, has equipment for manufacturing butter and maple sugar in addition to the ordinary machinery, and No. 7, a small farm with a percentage investment in equipment of 14.10, has a portable gasoline engine and wood sawing outfit, only a part of which possibly should have been charged to the farm. Aside from these two cases the variation of the percentage invested in machinery is small as compared with other classes of equipment.

DISTRIBUTION OF INVESTMENT BY ENTERPRISES

Reference has already been made to the division of investment by enterprises. Table VII shows the average distribution of capital for the 21 farms, on the basis previously set forth.

It will be noted that the land value is divided on the basis of acreage, no differences in quality of land on the same farm being recognized. This suggests that a farm inventory be made to show the relative value of the various kinds of land, as, for instance, waste, dooryard, pasture, barn lots, crop land, orchard and woodland. The crop land is included in one item under "All Crops," owing to the annual variation in acreage for the different crops.

The division of building values, based on the cubic space occupied by different enterprises, seems out of proportion, emphasizing, as it does, the much larger amount of space occupied in proportion to the value of property in the case of produce, supplies, etc., ($766.57) in storage than in the case of livestock ($436.51). The "produce and supplies" item under "buildings" might be divided between "All Stock" and "All Crops," but for the annual variation in the proportion of products fed and sold. The "All Stock" building charge is based on space devoted to sheds, alleys, etc., used by or used in caring for all or at least several classes of

stock. Buildings wholly or partially devoted to work shops or to the storage of machinery, wagons and tools give rise to the amount charged to "General Farm" ($325.42). A potato storage house and several sap houses were found. "Buildings" include both household and farm buildings.

The machinery and utensils charged to household ($11.07) were those which in some cases might be used either for domestic or farm purposes. Each class of livestock is charged with the articles pertaining directly to it, also each crop enterprise. Vehicles for transportation and a large proportion of the smaller tools are charged to "General Farm" ($237.29), and plows, harrows and other general crop machinery are charged to "All Crops" ($102.71).

In Table VIII are given by enterprises the percentages of total investment for 25 farms, together with the mean of the percentages for the 21 individual farms and the average percentages for the 21 farms considered as a unit. Miscellaneous enterprises are grouped under the column so headed. These include Maple Sugar, Syrup, etc., on Farms Nos. 1, 2, 5, 6, and 17; Orchard on Farms Nos. 3, 21, 22, and 23; Sugar Beets on No. 10; Tobacco on No. 24; and Market Garden on No. 25. On No. 4, 8.65 percent is invested in the Maple Sugar enterprise and 1.68 percent in Orchard; on No. 18, 0.28 percent is in Sugar and 0.92 percent in Orchard. Bees, also included with miscellaneous enterprises, average 0.03 percent of the total, amounting to less than 0.4 percent on any farm represented in Table VIII. On Farm No. 29, however, this enterprise represents 2.51 percent of the total investment.

The relative importance of the various live stock enterprises can readily be ascertained from Tables VII and VIII. On high priced land the "All Crop" enterprise naturally bears a higher proportion of the total investment. The investment in special crop machinery is relatively small. The low figures (.15, .10, .07, and .21) for corn machinery among the "hill" farms (Nos. 20 to 23, inclusive) are to be noted.

The distribution of capital for each farm is worthy of consideration by itself. It is not easy to generalize in this connection, all the factors discussed up to this point governing the selection of equipment. From the various tables, and especially from Table VIII, will be seen the difficulty of studying the farm as a unit instead of the enterprise. Farms Nos. 1, 2, 6, 9, 21, and 23 might be classed as dairy farms, yet the relative investment in various enterprises is far from uniform. With the exception of these, and Farms Nos. 20 and 25, the farms studied can best be classed as "general", and among these occur variations in the relative investment to understand which an analysis of the farm as a combination of enterprises is essential.

TABLE VII. AVERAGE INVENTORY OF 21 OHIO FARMS, SHOWING THE DISTRIBUTION OF INVESTMENT BY CLASSES OF EQUIPMENT, AND BY ENTERPRISE

Enterprise	Acres	Value of land	Buildings	Fences	Drainage	Water supply	Livestock	Machinery, etc.	Produce, supplies, etc.	Total	Percent
General farm	5.51	$ 246.44	$ 325.42	$533.95	$ 1.09	......	....	$237.29	......	$1,344.19	8.90
Household	2.04	91.01	1,437.05	......	.71	$ 72.48	....	11.07	......	1,612.33	10.70
Labor	.08	3.91	74.29	......	......	1.19	....	......	......	79.39	.53
Produce, supplies, etc.	...	....	766.57	......	......	......	....	......	$631.93	1,398.50	9.26
Horses	....	....	77.85	......	......	28.52	$ 891.66	77.46	......	1,075.51	7.13
Cattle	....	....	153.74	......	......	37.86	582.26	32.48	......	806.35	5.34
Sheep	....	....	65.50	......	......	10.81	201.05	3.06	......	280.42	1.86
Hogs	....	....	34.70	......	......	16.38	158.34	12.17	......	221.59	1.46
Poultry	....	....	40.83	......	......	4.53	52.60	4.89	......	102.85	.68
Bees	....	....	....	......	......	......	3.23	1.59	......	4.82	.03
All stock	46.50	2,037.10	63.89	......	2.14	......	....	10.59	......	2,113.72	14.00
All crops	85.71	4,157.92	....	......	362.48	......	....	102.71	......	4,623.11	30.63
Corn	....	....	....	......	......	......	....	83.38	......	83.38	.56
Small grain	....	....	....	......	......	......	....	70.98	......	70.98	.47
Hay	....	....	....	......	......	......	....	65.83	......	65.83	.44
Potatoes	....	....	3.57	......	......	......	....	20.44	......	24.01	.16
Sugar	2.98	122.27	6.05	......	......	......	....	35.36	......	163.68	1.08
Orchard	1.95	69.39	....	......	......	......	....	4.00	......	73.39	.49
Woodland	21.11	948.39	....	......	......	......	....	......	......	948.39	6.28
Beets	....	....	....	......	......	......	....	.59	......	.59	.004
Total	165.88	7,676.42	3,049.47	533.95	366.43	171.76	1,889.15	773.92	631.93	15,093.03	......
Percent	....	50.82	20.21	3.54	2.43	1.14	12.54	4.67	4.19	....	100.00

TABLE VIII. PERCENTAGE OF TOTAL FARM CAPITAL INVESTED IN EACH ENTERPRISE ON 25 OHIO FARMS, WITH MEAN AND AVERAGE PERCENTAGES FOR A GROUP OF 21 OF THESE FARMS

Farm No.	General farm	House-hold	Labor	Stor-age	Horses	Cattle and dairy	Sheep	Hogs	Poul-try	Bees	All stock	All crops	Corn	Small grain	Hay	Pota-toes	Misc.	Wood-land
1	4.47	13.00	....	5.88	1.76	11.86	....	1.07	.52	....	28.65	18.76	.60	.37	.23	....	1.64	11.19
2	10.01	10.70	....	9.50	7.86	16.40	....	.87	.88	....	13.54	19.15	.54	.49	.88	.38	.40	8.40
3	9.02	20.20	....	16.90	10.27	1.25	4.36	.08	.83	....	7.25	19.38	.29	.63	.37	.02	4.78	4.36
4	11.73	9.78	....	11.01	7.85	13.20	....	1.25	.61	....	9.91	22.25	.42	.47	.75	.07	10.33	....
6	13.60	12.11	....	7.87	13.08	8.10	....	.99	1.73	....	9.90	21.30	.61	1.65	1.01	.97	7.70	.28
7	19.15	8.89	....	7.72	17.65	3.20	2.96	.97	1.72	.39	14.32	17.55	.45	.01	.59	1.43	.....	3.00
8	8.83	16.45	....	6.75	3.34	1.53	....	3.61	.63	....	11.10	47.19	.13	.10	.66	.01	.....	.67
9	6.03	9.50	2.74	10.36	3.95	7.65	....	1.36	.33	....	11.60	33.19	1.49	.74	.31	1.42	.....	9.33
10	9.36	12.00	....	7.16	7.19	3.06	1.02	.48	1.33	....	2.50	52.50	.10	.38	.61	.31	.08	1.92
12	7.20	9.81	....	15.21	11.29	3.48	....	2.18	.47	.04	7.64	35.92	.93	.53	.28	....	.....	5.02
13	9.40	15.00	....	12.85	8.53	3.04	1.17	1.51	.93	....	7.89	34.82	.36	.52	.41	.07	.....	3.50
14	6.64	5.31	....	6.85	6.22	4.37	.24	2.19	.14	.02	21.31	35.76	.52	.39	.20	....	.....	9.84
15	8.18	7.00	....	7.08	7.64	3.96	....	2.44	1.02	....	19.23	37.35	1.19	.50	.12	....	.....	4.20
16	9.55	6.63	....	6.63	9.04	1.42	.88	1.81	.39	...	4.35	42.96	1.61	.63	.21	....	.....	14.22
17	7.73	9.75	1.55	2.96	3.57	7.24	2.83	....	.42	.01	19.95	30.07	.37	.38	.20	....	6.07	6.90
18	8.50	9.22	....	12.02	3.46	1.21	4.79	3.70	.52	....	7.60	34.40	.50	.44	.70	....	1.22	11.69
19	8.80	8.80	....	17.40	11.10	11.60	....	1.80	.90	....	9.20	25.80	.50	.40	.90	.30	.....	2.50
20	11.17	4.38	3.10	10.62	7.92	1.15	11.75	....	.42	.26	23.37	22.62	.15	.20	.56	.26	.....	2.06
21	13.92	16.29	1.91	6.33	6.42	7.18	3.08	1.12	.59	.02	12.50	13.74	.10	.39	.38	.06	.94	15.01
22	8.28	17.90	....	7.32	8.73	4.51	5.27	....	1.98	.12	31.07	9.31	.07	.08	.44	....	.97	3.95
23	12.20	15.36	....	8.57	8.15	9.44	....	1.03	.72	.09	17.52	20.52	.21	.53	.55	.26	2.78	2.07
Average of 21 farms	8.90	10.70	.53	9.26	7.13	5.34	1.86	1.46	.68	.03	14.00	30.63	.56	.47	.44	.16	1.57	6.28
Mean av. of 21 farms	9.70	11.337	.443	9.365	7.85	5.945	1.827	1.354	.813	.045	13.780	28.325	.53	.472	.493	.264	1.759	5.719
24	7.70	16.05	.. .	3.12	11.00	3.40	1.72	1.05	.66	.13	17.60	27.60	.38	.43	.12	....	.47	8.60
25	12.40	29.57	....	.58	9.50	3.36	....	..	19.43	....	.96	23.13	.14	.29	....	....	.64	....
5	8.74	18.56	1.12	16.02	6.04	4.49	5.59	.57	.47	....	11.65	19.04	.45	.27	.39	.02	.35	6.23
11	7.49	5.95	....	6.81	6.59	4.52	3.53	1.19	.75	....	4.70	46.00	.73	.63	.35	....	.77	9.99

EQUIPMENT OF THE AVERAGE FARM

In the foregoing pages the distribution of capital at the time of inventory has been discussed. The next phase of the study, and really the first in order, is the enumeration of the items that go to make up the equipment of an average farm. The average equipment of the 21 farms which have been studied will, of course, apply only to farms having approximately the same conditions as this "average farm." The various classes of equipment will be dealt with separately in the following pages and sufficient detail given to permit the application of the data to farms diverging from the type under consideration. It is impossible to make a general recommendation as to equipment owing to the complex and varying combinations of enterprises on different farms, and the summary presented later is valuable in a suggestive way only.

REAL ESTATE

The average value previously shown for the bare land is taken as a basis instead of the mean, as all other data relating to the first cost of equipment are based on averages. The cost and present value of drainage systems were regarded as equal, as before stated, but the first cost of buildings, fences, and water supply will be higher than the values shown in the previous pages. The various improvements will be discussed separately.

HOUSEHOLD BUILDINGS

The great variation in the tastes and circumstances of different farm owners is largely responsible for the variation in the cost of household buildings, and it is almost impossible to arrive at a satisfactory basis for determining the proper outlay in this direction.

It has been shown (Table VII) that on the 21 farms studied the inventory value of household and tenant buildings was approximately equal to that of farm buildings, each being about $1500. This, however, does not represent the present cost of construction. Household buildings were not studied closely as to size and cost, but from the values shown in Table III, and such data as are at hand it is estimated that to replace those found on the 21 farms would involve an expenditure of from $600 to $4000 per farm averaging close to $2500. This would include dwellings for proprietors, tenants, or laborers, wood houses, smoke houses, and milk cellars, ice houses, etc., which might also be used to some extent for the farm.

SPACE NEEDED IN FARM BUILDINGS

The farm buildings must usually provide for the shelter of horses, cattle, sheep, hogs, and poultry, and for a certain amount of space to be used by or devoted to the care of several classes of livestock. They must usually accommodate all or a large part of the products of the farm fields, including roughage, grain, and seed.

They should provide space for the storage of all wagons, machinery and tools, and for the farm workshop. A certain amount of easily accessible space should be available also for convenience in the temporary shelter of machinery, livestock, or products. Buildings for special purposes, such as the storage of root crops and ensilage, and the manufacture of maple products, are necessities on only a part of the farms.

In studying this problem the size and plan of each building was noted, together with the enterprise to which each portion of the building was devoted at the time. The amount of floor and cubic space devoted to the various enterprises has thus been approximated. (The thickness of walls and partitions was not considered.) While averages of the 21 farms do not include enough cases to justify the drawing of general conclusions, the data contained in Tables IX and X afford a rough working basis.

In Table IX are included data concerning enterprises the space for which depends to a considerable extent upon the size of the farm. Under "General Farm" is included all space devoted to machinery storage, work shop, driveways, and other spaces devoted to the farm as a whole. "Hay Storage" includes the area and volume of mows and lofts. The volume, in this case, is greater than the space ordinarily filled with hay or other roughage. The proportion of the entire volume of mows which could actually be filled by the ordinary methods could not be satisfactorily determined at the time, and the space usually filled was extremely variable, hence the total volume was used in this table. "Grain Storage" includes separate cribs and granaries, also all bins and storage places for grain and seed in other buildings.

TABLE IX—AVERAGE FLOOR AND CUBIC SPACE DEVOTED TO THE STORAGE OF PRODUCTS, MACHINERY, ETC., IN BUILDINGS ON 21 FARMS

Enterprise	Average Space per farm		Average Space per acre		Average Space per acre of crops	
	Floor	Cubic	Floor	Cubic	Floor	Cubic
General Farm	2,038	24,732	12.3	149.0	23.7	288.5
Hay Storage......	2,752	46,558	16.5	280.6	32.1	543.2
Grain Storage.....	505	5,192	3.0	31.3	5.8	60.5

The average space per acre shown in Table IX would tend to increase with a decrease in the size of farm and vice versa. On the smaller farms the amount of waste space would be greater for each enterprise and the space devoted to certain general farm purposes would remain practically the same as for the larger farms.

In Table X are shown averages in connection with the space devoted to livestock enterprises. In order to obtain comparable units all young stock except colts was reduced to the basis of mature animals. Two head of young cattle, 2 shoats, or 5 pigs were regarded as equivalent to one mature animal. Since young lambs are later included with the ewes in Table XIII no correction was necessary. The space in harness rooms is included in that shown for horses, and space devoted to milk rooms, etc., in that shown for cattle. For sheep the space includes both floor and rack room, with very little waste. For swine the space shown includes feed alleys, etc., in hog houses. The average space per head is, of course, much too small for the entire herd of swine. Only 11 out of 21 farms show a definite space devoted to swine, and on the other farms swine usually occupy a portion of the "All Stock" space during part of the year. Portable houses for the brood sows are in quite common use. These, averaging 4.1 per farm, were included with the miscellaneous items of equipment rather than with permanent farm buildings.

TABLE X—AVERAGE FLOOR AND CUBIC SPACE PER FARM AND PER HEAD DEVOTED TO LIVESTOCK ENTERPRISES IN BUILDINGS ON 21 OHIO FARMS

Enterprise	Average No. of mature Animals per farm	Average Space per farm		Average Space per head	
		Floor	Cubic	Floor	Cubic
Horses	7	613	5242	87.5	748.8
Cattle	13	1084	9210	83.4	708.4
Sheep	41	475	4141	11.6	100.9
Swine	17	327	2912	19.2	171.3
All Stock	..	448	3925	....	.....

SIZE OF FARM BUILDINGS

It is possible to plan a practical set of farm buildings which will almost exactly fit the conditions of the "average farm" under consideration. The size and nature of the buildings must, of course, be varied to fit any individual conditions, but assuming that the data in Tables IX and X give the requirements for this particular size and type of farm, the size of the separate buildings is the next item to be determined.

BARN

Of the barns on the 21 farms about half were basement or "bank" barns, and in case of the greater number of the remainder the space equivalent to a basement was secured by attaching to the barn unsightly sheds of the "lean-to" type. In the majority of

cases there could be had a convenient site for a basement barn without excessive grading, and the advantages of this type are such that they will be provided for in the barn to be planned.

Horses, cattle, and sheep are often found in the basement of a barn. In this case a barn 36 ft.x60 ft. will provide [illegible]60 square feet of floor space (outside measurement), while the requirements for the three classes of stock total 2,172 square feet, these also being calculated on outside measurement. A section 16 ft. x 36 ft. at one end will provide 576 square feet for horses, and an additional space 4 ft. x 9 ft. for harness would utilize the average space allotted to this enterprise. The 16 feet would be reduced by the thickness of the wall, but would leave ample room for manger, stall, and alley behind the horses. The 7 horses could easily be accommodated in the width remaining after the thickness of one wall is deducted from 36 feet. As a rule, in barns of this kind, the basement wall is provided on three sides only, the two ends and the long side next the bank.

A section 30 ft.x36 ft. would provide 1,080 square feet for cattle where 1,084 are required. This would afford ample space for the average of nearly 8 cows per farm, for the young and miscellaneous stock, and for a milk room if considered advisable to place one there. It would afford room for the miscellaneous stock on a beef farm and feeding room for a small carload of steers. The sheep would preferably be lodged in the center space, in which the harness room and a stairway could be located. Deducting the area of the harness room from the remaining space, 14 ft. x 36 ft., there are left 468 square feet for sheep where 475 were needed. A height of 8 ft. 8 in. would supply 18720 cubic feet in the basement, while 18,593 cubic feet are required. In this plan both horses and cattle are provided with more and sheep with less cubic space than called for by the average. A basement somewhat similar to the one just described was found on farm No. 3.

The upper part of this barn is adapted from that of a barn 40 ft. x 60 ft. on farm No. 14. A central driveway 14 feet wide extends through the center of the barn, making a floor space 14 x 36 feet available for general farm purposes. To the left of the driveway is a staircase to the basement, the remainder of this end of the barn being devoted to hay storage. On the right of the driveway a grain room 10 ft. x 23 ft. and a space 26 ft. x 23 ft. for storage of wagons or machinery occupy the floor space. A mow floor extends over these spaces at a height of 8 ft., and over the driveway at a height of 12 ft. The barn is 18 ft. from the top of the basement wall to the corners, or to the "square," and a roof of ⅓ pitch gives an additional height of 12 ft. to the point of the gable. This provides 2,160 feet

of floor space for hay, and 230 for grain storage, though volume is rather the essential in this case. It provides 39,168 cu. ft. for hay and 1,840 cu. ft. for grain, leaving a balance to be provided for hay of 7,390 cu. ft., and for grain of 275 sq. ft. and 3,352 cu. ft. In the driveway 14 x 36 and storage space 26x23, an area of 1,102 sq. ft. and a volume of 10,832 cu. ft. are provided for general farm purposes, leaving a balance of 936 sq. ft. and 13,900 cu. ft. to be provided for by other buildings.

The cost of this barn will vary with many factors. This can more easily be estimated by the contractor than the necessary size, hence the latter point only was emphasized in this study. A study of costs of four comparatively new barns of similar type indicates that about 2½ cents per cubic foot enclosed will cover the cost of a barn of this size and type. It is a common practice among Ohio farmers who have timber available to utilize a considerable amount of lumber sawed upon the farm and the exact value of this is difficult to estimate. This barn contains 70,560 cubic feet and at the rate given it would cost close to $1,800, but this is probably a low estimate.

HAY BARN

Where a basement barn is not practicable there is usually a second building for the storage of hay and the shelter of a part of the live stock. In some cases this is made large enough so that sheds attached to the barns are dispensed with. In order to provide for the additional space required for "all stock" (448 square feet and 3925 cubic feet) and for the additional storage of hay, a building of this sort is here planned for the "average farm" supplemental to the above planned barn. To combine the cubic space required for both purposes with the floor space required by "all stock" would result in a building of unusual proportions, hence the ground area is increased from 448 to 512 feet as shown in Table X. A building 16 ft. x 32 ft., 16 ft. to the "square", with roof given one-half pitch will give an excess of 64 square feet and 171 cubic feet for "all stock." It will also provide 6144 cubic feet for the hay storage, as compared with the remaining requirements of 7390 cubic feet, if the second floor is placed 8 feet above ground. A further increase of floor space accompanied by a decrease in height would improve the proportions of the building, though they are not unusual. As this building may be of cheap construction $150 should cover the cost.

WAGON SHED, CRIB, ETC.

The grain room in the large barn failed to provide for a large part of the space required for grain storage. The ratio between floor and cubic space remaining suggests a high crib or granary.

A popular building is a double crib, or a combination of crib and granary, with a driveway between, which, when enclosed by doors at either end, may be used as a convenient wagon or buggy shed. A building 20 ft. x 28 ft. on the ground and 10 ft. in height, with an 8-foot gable, is suggested. Two cribs, each 5 ft. wide, and a driveway 10 ft. wide, all extending the length of the building, would occupy the floor space. For grain storage this building would provide 3,360 cubic and 280 square feet, or almost exactly the remaining balance of the required amount, i. e., 275 sq. ft. and 3,352 cubic feet. Including the loft above the driveway which could be used for the storage of light implements, ladders, etc., 3,920 cubic feet would be provided for general farm purposes and 280 square feet of ground space. This building, built with the average finish, would probably cost from $200 to $250.

MACHINERY SHED AND WORKSHOP

In the large barn planned and in the above combined wagon shed and crib there was provided an area of 1382 square feet and 14,752 cubic feet for general farm purposes. There still remain balances of 656 sq. ft. and 9,980 cubic feet to be devoted to these purposes, if the requirements as set forth in Table IX are complied with. The storage of a part of the farm machinery and the location of the farm workshop have not been provided for; hence, a building 22 feet by 30 feet, and 12 feet in height to the eaves is designed to meet these needs. If a workshop were finished off, the building would probably cost from $250 to $300.

HOG HOUSE

Only part of the farms have separate permanent hog houses. The average floor space devoted exclusively to hogs on the 21 farms was 327 feet. A house 12 ft. x 27 ft. would furnish this and provide for a 4-ft. feed alley the length of the building and 4 pens 8 ft. x 6¾ ft. With this building, several portable houses, and the occasional use of space in other buildings, the average herd shown in Table XIII viz., 1 boar, 6 brood sows, 22.1 shoats and 20.5 pigs could be accommodated. If the house were made 10 ft. high in front and 8 ft. in the back, with a shed roof, the average requirements as to cubic space would be met. The probable cost of the hog house would be from $60 to $100.

POULTRY HOUSE

Poultry houses on 5 farms besides the 21 which have been under discussion are considered in the following averages. The average flock on these farms was equivalent to 106 hens, or a trifle larger than on the 21 farms. The floor space per hen varied from 1½ to 11.7 square feet on different farms. Excluding the latter case the mean was 3.46 square feet per hen. The mean cubic space

per hen was 24.4 ft., indicating 7 feet as the average height of houses. In 40 percent of cases the area per hen was between 1½ and 2½ square feet; in about 40 percent of cases the area of the poultry house was between 150 and 250 square feet, and in 60 percent of cases the number of fowls kept in one house was between 60 and 120. In the remaining cases there was a wide variation. To house the 106 fowls at the mean rate of floor space per fowl would require an area of 367 sq. ft. of floor space, which would be provided approximately, by a house 12 ft. x 30 ft. Five square feet of floor space per hen is often recommended by poultry authorities, and 4 square feet per hen should be considered as a minimum in good farm practice but 60 percent of this area is apparently closer to actual conditions on most farms, and a house 12 ft. by 20 ft. is probably nearer the average than one 12 ft. x 30 ft. A house for the accommodation of the flock of average size should not be less in floor space than 12 ft. x 36 ft. or 16 ft. x 27 ft., or better still would be two houses 12 ft. x 20 ft. In this latter case the one-year-old fowls could be kept in the one house and the two-year-olds in the other and the difficulty of separating the old from the young would be obviated. The poultry had free range on practically all the farms. The poultry house would represent an outlay of from $50 to $75 on the average farm.

SILO

Silos are usually associated with the cattle enterprise. Six wooden silos of from 100 to 120 tons capacity were found, 4 in connection with dairy cattle and two with beef cattle. These cost from $150 to $250 in place, depending upon the size and material.

SAP HOUSE

Where a "sugar bush" is turned into revenue a separate building is usually found advisable. This often consists of a room for the evaporator, etc., and a woodshed. It is ordinarily built of old or rough lumber and as cheaply as possible. A building 18 ft. x 32 ft., 8ft. high, with roof given ⅓ pitch is close to the average of three sap houses found on these farms.

MISCELLANEOUS BUILDINGS

On many farms there are buildings for special purposes not already discussed. On farm No. 9 is a potato cellar costing about $75. On farm No. 29 there is a bee house for storing the bees, hives, etc., during the winter. An occasional well house is included under water supply. An investment of $75 per farm would probably be an average for silos, sap houses, and other farm buildings of a miscellaneous character, on the 21 farms.

SPACE UNITS IN FARM BUILDINGS

From the foregoing discussion it will be apparent that there is great need for definite space units to be used in the planning of farm buildings. The usual division of crops on the 21 farms studied makes it necessary to provide for storing the yields from 25 to 30 acres each of corn, small grain, and hay. Yields of 50 bushels of corn to the acre from 28 acres, 20 bushels of wheat from 14 acres, and 40 bushels of oats from 14 acres would require approximately 4,550 cubic feet of space, which is more than provided for on the average, since some of the corn is used for silage and some of the grain is sold immediately. Maximum yields, however, could encroach on the 'General Farm" space. A hay yield of 2½ tons to the acre from 28 acres would tax the capacity of the mows provided on the average farm (165.88 acres) and straw would ordinarily have to be stacked outside, especially if corn stover were shredded.

The units of space for field products are well understood, however, in comparison to those for livestock and general farm purposes. The averages presented are simply those of actual conditions on a small number of farms, and it is a matter of common observation that most farm buildings can not be regarded as models of economy and convenience. Units of space for each class of livestock, including the area occupied by the animal itself, the racks or mangers, alleys, and the feed of the animal, would be of great assistance in the planning of buildings for economy of space. These can not be worked out satisfactorily on theoretical grounds, but should be obtained from a careful study of the best farm practice.

FENCES

The study of the extent of fence on the 21 farms yielded some interesting data which are presented in Tables XI and XII. In Table XI are given the total rods of fence maintained by each farm, divided into outside or line fence, inside fence, and road fence. Only the total fence kept up by the owner is represented, hence the amount of line fence should be doubled in order to get the total number of rods touching the farm. The first cost of fence per acre is affected not only by the character of the fence but by the number of rods per acre. The effect of a large amount of road fence on the latter may be seen by contrasting farms Nos. 7 and 8, having 284.1 and 333.9 rods of road fence respectively, making the average rods per acre 13 and 10.4 respectively, with Nos. 1 and 2, which have 6.1 and 4.9 rods respectively of road fence. Under "road fence" is included river or other outside fence not shared by an adjacent owner. Naturally the smaller farms show a greater extent of fence per acre than the larger, but this is not necessarily

true in every case. The average of all the farms shows approximately one-half the fence inside, one-fourth on the road, and one-fourth between the farm and those adjacent. A slight discrepancy is shown between the acre value of fences in Tables IV and XI, as in the former the total value of fences on each farm was brought to a round number, while in the latter the actual value is used.

TABLE XI—TOTAL RODS OF LINE, ROAD AND DIVISION FENCE MAINTAINED BY THE OWNERS OF 21 OHIO FARMS, WITH COST, VALUE AND NUMBER OF RODS PER ACRE

Farm No.	Acres	Owner's share of line fence	Road fence	Inside fence	Total owner's fence	Cost of fence per acre	Value of fence per acre	Average rods per acre
		Rods	Rods	Rods	Rods			
1	116 20	365.8	11.9	330.	707.7	$ 2.49	$ 2.11	6.1
2	164.11	351.2	......	444.8	796.	1.76	1.52	4.9
3	104.25	125.2	220.3	710.7	1056.2	5.88	4.37	10.3
4	108 34	124.8	202.4	405.6	732.8	4.36	2.71	6.8
6	143.32	422.6	180.8	538.4	1141.8	5.48	3.94	8.
7	49.61	119.8	284.1	241.4	645.2	9.01	4.50	13.
8	78.64	140.1	333.9	344.3	818.3	5.20	5.08	10.4
9	147.67	119.8	128.1	224.4	472.7	1.61	.65	3.2
10	100.00	129.6	178.	803.2	1110.8	7.64	5.89	11 1
12	156.97	354.9	79.2	609.	1043.1	3.36	2.57	6 7
13	198.25	735.0	475.	1060.	2270.	7.50	5.72	11.4
14	388 92	285.4	713.6	856.4	2419.2	3.82	2.29	6.2
15	219.82	258.4	537.6	727.6	1523 6	4.86	3.65	6.9
16	172.52	268.8	141.2	596.	1006.	4.36	3.63	6.2
17	275.99	416.4	539.2	864.8	1820.4	5.67	3.86	6.6
18	207.83	324.0	375.2	827.6	1526.8	4.54	1 51	7.4
19	103.81	......	......	......	997.	5.06	3.87	9.6
20	165.25	505.6	77.2	1027.6	1610.4	5.03	3.56	8 7
21	228.62	176.4	390.8	956.8	1524.	4.	3.60	4 9
22	156.00	329.2	190.8	579.6	1099.6	3.24	2.35	4.8
23	177.27	291.0	409.1	734.1	1434.1	5.80	4.06	8.1
Average	165.88	292.19	273.26	644.11	227.93	4.60	3.25	7.4
Percentage	......	24.1	22.5	53.2	1100.	....	....	....
Mean	......	......	......	......	......	4.79	3.40	7.67

The character of fences on the 21 farms is brought out in Table XII, which shows the extent of each of the eight principal kinds of fence and the average cost per rod of all fence on each farm. The total of the eight kinds shown averages 1,204.6 rods per farm, or over 98 percent of the total, a few miscellaneous kinds being omitted. The cost of the various kinds of fence varies with the difference in the cost of materials in different localities, but even more with the height, number of wires or boards, distance apart of posts and the labor expended in construction. "Woven wire" fence, for instance, might be 5 feet in height without barbed wires in addition, or 3 feet in height with several barbed wires above and one below. It might be made of either heavy or light wire, with posts from 10 to 33 feet apart, the posts costing from 10 to 30 cents each. Owing to these variations, estimates on the cost of construction can hardly be made general.

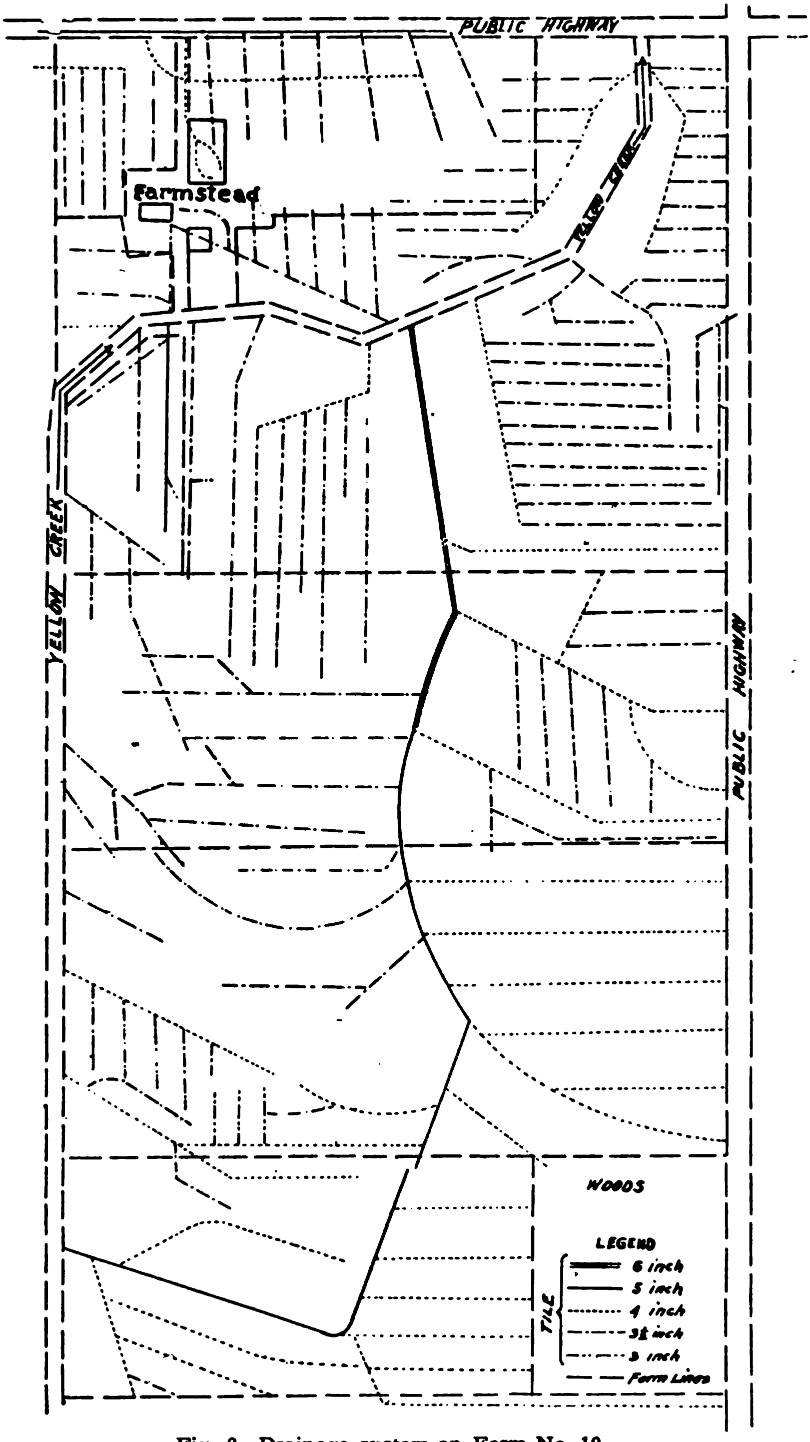


Fig. 2 Drainage system on Farm No. 10.

The old "zigzag" or "worm" fences are still much in evidence, but as they decay are being replaced largely by woven wire. A small percentage have been rebuilt as straight rail fences. The use of barbed wire is somewhat restricted by law, but it is popular as a cattle fence. Board and picket fences, the latter usually made of wire and pickets, are still used somewhat for tight fencing but are being replaced by woven wire. The hedge fences (usually of osage orange) are being torn out on many farms not only because of their unsatisfactory character and the labor of keeping them in shape, but because of the ground rendered unproductive on either side of the fence row. The smooth wire fences include various kinds of wire, many of which have been put out in the effort to supply a fence safer than barbed wire and easier to put up than woven wire.

TABLE XII—NUMBER OF RODS OF EACH PRINCIPAL KIND OF FENCE MAINTAINED BY THE OWNERS OF 21 OHIO FARMS, WITH THE AVERAGE FIRST COST PER ROD OF ALL KINDS OF FENCE ON EACH FARM

Farm No.	Woven wire rods	Barbed wire Rods	Smooth wire Rods	Board Rods	Worm rail Rods	Straight rail Rods	Picket Rods	Hedge Rods	Av. cost per rod Cents
1	70.3	448.2	......	......	123.5	65.7	......	......	40.9
2	......	140.	......	......	602.	6.	48.	......	36.4
3	50.8	......	81.	34.7	624.5	20.	245.3	......	58.0
4	126.4	......	36.	28.	277.6	......	24.	240.8	64.5
6	612.4	......	272.8	80.	20.	133.8	22.8	......	68.7
7	28.5	104.7	......	113.8	134.	26.	......	47.7	69.4
8	225.	......	......	......	130.6	......	462.8	......	50.
9	134.8	......	......	31.2	306.2	......	......	......	50.
10	586.	......	......	119.2	371.2	20.8	13.6	......	68.6
12	348.7	......	493.6	......	200.8	......	......	......	50.4
13	720.	30.	......	140.	1140.	93.	37.	110.	65.5
14	605.	643.6	......	71.6	464.8	535.8	98.2	......	61.4
15	302.1	680.8	142.4	268.	109.2	......	21.2	......	70.
16	186.4	422.8	......	......	126.8	......	270.	......	74.8
17	986.	......	......	216.4	310.	......	232.8	75.2	86.
18	214.4	......	......	267.6	773.6	......	271.2	......	61.8
19	......	......	180.	245.	408.	60.	104.	......	52.3
20	305.2	614.8	59.6	202.8	374.8	53.2	......	......	57.8
21	356.8	30.4	18.	68.	723.6	86.8	240.4	......	60.
22	208.8	......	......	50.8	811.8	8.	20.2	......	46.2
23	211.3	765.6	52.	88.	228.3	......	36.5	52.3	71.7
Average	299.	184.8	63.6	96.4	393.4	38.5	103.7	25.1	59.7
% of total	24.8	15.3	5.2	8.	32.6	3.1	8.6	2.	....

Regarding the cost of construction at the present time, it may be said that this applies almost entirely to board and barbed or woven wire. Hedge fences were formerly installed at about one dollar per rod, and required from 5 to 10 cents per rod per year for trimming. Reference has already been made to the cost of building old rail fences. The labor cost probably ranged between 30 and 50 cents per rod. The material was not valued, and in fact often had no market value at the time the fence was built. The rebuilding of rail fences costs 20 to 30 cents per rod for labor, and if the rails are fastened to posts, one post will be required for each 11-foot

rail length. Picket fences require from 1 to 1¾ posts per rod. The pickets, wire, etc., cost from 60 cents to $1.00 per rod, and the labor of erecting from 15 to 20 cents per rod. None of these types are now built to any great extent.

Barbed wire fences for cattle usually consist of 3 or 4 wires at a cost of 3 to 4 cents per rod for each wire. Intermediate posts are usually set at from 11 to 22 feet apart, costing 5 to 8 cents per post for setting. They are of oak, chestnut, catalpa, osage orange, locust and cedar, principally, costing anywhere from 10 cents up. The corner and brace posts cost from 50 cents up for the posts, and from 50 cents to $1.00 for setting.

Woven wire costs from 25 to 75 cents per rod for the usual heights and grades, the lower heights usually taking several strands of barbed wire in addition. As a rule, posts are set from two-thirds to two rods apart. Setting of posts for woven wire fences costs about the same as for barbed wire, but the end posts must be heavier and more firmly braced, costing as high as $3.00 in some cases for post and setting. The labor of erecting wire fences, outside of setting posts, is estimated at from 5 to 10 cents per rod, but accurate figures are not easily available. This refers, of course, to ready made fence, i. e., not woven on the ground.

Board fences usually require two or more posts, and from 25 to 40 feet of lumber, per rod. The rise in price of fence lumber has practically restricted board fences to the lots about the farmstead. While the estimates must be varied to suit conditions, it is probable that from 45 to 60 cents per acre for barbed wire, 60 to 90 cents for woven wire, and from $1.25 up for board fences will cover the cost.

DRAINAGE

The investment in artificial drainage shown in Table VII represents the cost of installing such improvements. Only a few farms have practically all fields drained. Figure 2 represents the drainage system on Farm No. 10, as shown on the owner's map, all of the farm except the woodlot being tile drained. The owner's map shows the size, depth and location of all tile, this being very convenient when drains are to be cleaned or new ones installed. The cost of the drainage on this farm was $17.70 per acre for the whole farm and about $18.60 per acre drained.

The average of the 21 farms showed an investment of $366.43 per farm for drainage. At the rate prevailing on farm No. 10, this would tile about 20 acres thoroughly. In practice, however, "strings" of tile are found only in the low places, and a much larger area could be drained. The work of digging the ditches and laying the tile is often done by contract at the rate of from 6 to 10 cents per

"rod foot" for small tile, i. e., a ditch 1 rod long, 1 foot deep, and wide enough to allow the placing of tile from 2½ to 5 inches in diameter. Ditching machines usually do the work somewhat cheaper than it can be done by hand. The cost of ditching for larger tile is greater, but not in proportion to the size of the tile, reaching 12 to 16 cents per rod foot for 12 and 15 inch tile. Filling the ditches is usually done with a team and plow at a very slight cost. The tile varies in price with locality. The 2½ inch tile costs 14 to 16 cents per rod; 3 inch, 16 to 20 cents; 4 inch, 19 to 25 cents; 5 inch, 30 to 36 cents; 6 inch, 40 to 50 cents; 8 inch, 70 to 80 cent; 10 inch, $1.00 to $1.40. These figures are from farmers. Tile is frequently sold by the hundred or the thousand, 16 pieces being counted to the rod.

WATER SUPPLY

Owing to the wide variation in the character of water systems, it will hardly be possible to make even an approximate list of the essentials for the average farm. The average present value of the water system, appraising wells at the cost of installation, and pumps, tanks, etc., at their present value, is seen to be $171.76 (Table VIII) for the 21 farms. Allowing for depreciation on the latter items, it is probable that the average cost would reach $225 for the entire system. Between different farms, however, there is a wide range, as shown by Table III. The larger number of these farms depend upon dug wells from 25 to 40 feet in depth and from 3 to 4 feet in diameter. Such a well, for digging and walling, costs $1.00 to $1.25 per foot in depth. A hand pump, costing from $5.00 to $10.00 is usually found in this sort of well. Some of the farms have drilled wells from 90 to 150 feet deep. These cost in the neighborhood of $1.00 per foot for drilling and casing, and require a more expensive pump, costing from $15 to $25 for the pump, piping and cylinder. One or more cisterns are usually found, ranging in size from 20 to 150 barrels and costing from $10 to $35. A cistern pump complete usually costs from $4.00 to $6.00. Where water is conveyed to tanks or troughs at some distance from the well, piping of 1 or 1¼ inch is ordinarily used, at a cost of from 8 to 12 cents per foot. Small wooden troughs, holding from 1 to 3 barrels and costing from $3.00 to $5.00, are often used in connection with wells or cisterns near the barn, but tanks holding from 10 to 50 barrels are commonly used in feed lots. These cost from $10 up, in wood, and a trifle more in concrete. Many permanent concrete tanks are being installed by farm labor at a cost of from $15 to $40 for sizes ranging from 20 to 80 barrels. Windmills costing from $50 to $150 are often found economical. The usual height of tower is from 25 to 30 feet,

with a wheel 6 to 8 feet in diameter. These cost in the neighborhood of $60 to $70. Gasoline engines used only for pumping are occasionally found. These are usually of 2 or 3 horsepower and cost from $75 to $150. Reservoirs are sometimes found necessary in connection with deep wells and windmills. These store up a surplus of water at a depth from which it can be easily pumped by hand when a lack of wind cuts off the supply from the well. The cost of construction is about the same as for cisterns.

PERSONAL PROPERTY

The requirements of the average farm as to livestock and machinery are discussed in the following pages, including Table XIII, which was compiled from the inventories.

HORSES

In Table XIII the horses and mules on the 21 farms are divided into 5 classes with respect to use. The general purpose, draft, and draft and brood classes might be grouped as work animals, with an average of 4.48 per farm, but the subdivision indicates a little more clearly the character of the animals. The draft and brood animals are mares regularly worked rather than mares kept for breeding purposes only. The general purpose animals are those used for both work and driving on several small farms. The data indicate that 4 work horses, 2 head of young stock, and either a driving horse or brood mare, which may occasionally be worked, as about the average requirements as to horses.

The 94 horses used partially or wholly for heavy work on the 21 farms averaged 1250.3 pounds in weight. From Table II it will be seen that these farms averaged 85.71 acres of harvested crops. This would mean an average of 19.13 acres of crops per work animal. The acres of crops per work animal varied from between 10 and 11 acres on farms Nos. 3, 7 and 22, to 31.1 acres on farm No. 17. Taking all the farms visited by Mr. Thompson and all those of the statistical cooperators, 55 in all, there was an average of 8.4 horses per farm. Fifty-four of these farms from which data were more complete averaged 199.55 acres in size and 125.54 acres in harvested crops. There was an average of 5.39 work horses per farm and an average of 23.3 acres of harvested crops per work animal. On one group of 27 farms, averaging 153.65 acres in size, there were 18.9 acres of crops per work animal, and on a group of 17 farms averaging 272.44 acres, the average crop area was 27.5 acres per work animal.

The farms visited by Mr. Thompson were mostly in the level "large farm" area of Ohio, i. e., the southwestern part. Seventeen farms visited by him in 1907 and 1908 maintained 119 work horses, averaging 1,368 pounds in weight, with an average value of $158.91

and an average age of 8.98 years. On farms Nos. 20 to 23, inclusive, in the "hill section," 17 work animals, averaging almost exactly 7 years in age, and 1170 pounds in weight, were valued at $146.41 each. These farms average 186.79 acres in size, but average only 65.4 acres in crops, or 15.4 acres per animal. Fifty-two farms, including those of cooperators, maintained 275 work horses, averaging 1,306 pounds in weight.

The work stock, like machinery, is seldom utilized to its full capacity on small farms or where conditions cut down the crop area. The number of work animals needed depends not only upon the acreage of crops but upon the total area of the farm, the kind and extent of livestock enterprises, the kind of crops, the topography, the distance of the farm from town and numerous other factors which could not be studied in detail at this time. In most cases the number of work animals is determined by the minimum power requirements during the two busiest seasons—seed time and harvest.

CATTLE

The values for cattle on these farms in the winter and spring of 1909 are approximated in the column of costs per unit. These will, of course, fluctuate with the market and the round numbers are used for convenience. They are based, however, on averages except as otherwise stated. One hundred dollars has been set arbitrarily as a fair price for a good bull of either a beef or dairy type, and $40 has been taken as nearer the usual value of a beef cow than the actual average on two farms reporting. On one of these there were 14 Shorthorn cows valued at $100 or more each, and on the other there were 4 grade cows valued at $35 each. Steers were figured on the prices of 4 to 4½ cents prevailing at that time, and young beef stock at about the average value per head.

On farms Nos. 1, 2, 6, 9, 21 and 23, on which dairying is the principal enterprise, there were 95 milch cows with an average value of $40.84 per head. These included some pure bred cows. On 10 other farms there were 29 milch cows, averaging $37.72 per head. The average value of 124 cows on 16 farms was $40.18 per head. The 6 dairy farms averaged $648 worth of milch cows per farm and the 10 other farms $109.40 per farm. On the 6 dairy farms there were 44 head of young stock, or nearly 1 head for each 2 milch cows. The figure for the value of young stock is close to the average for all calves and heifers found on these farms.

SHEEP

The value of $10 per ram is a trifle higher than would be true of many farms, owing to the presence on Farm No. 17 of a number of rams at $12.50 each which were raised for sale as breeding

animals. This figure given, however, is none too high for good results. All lambs at foot are included in the value of the breeding ewes. Feeding wethers, lambs and ewes are grouped under "Wethers, etc."

SWINE

Swine are quoted at a round figure approximating the average value on these farms at that time, as follows: Boar $15; sow $14; shoat $6.25; pig $2.50. Several fat hogs are included under "Shoats," and the dividing line between "shoats" and "pigs" is not absolute. About 5½ cents per pound was the farm value of hogs at the time the inventories were taken.

MACHINERY, TOOLS, ETC.

As stated elsewhere, the first cost of the great number of minor articles of farm equipment not mentioned in Table XIII would probably be from $200 to $300 by the time the outfit was complete for the average Ohio general farm of 160 acres. This figure, however, would include an appropriation of $50 or more for repair materials, which in this report are invoiced with produce, supplies, etc. Taking all the minor items other than repair materials for 33 farms, using the ordinary retail prices and dividing by the number of farms, the first cost of minor items for the average farm of 167 acres was found to be about $190.

In taking an inventory of the small items many were doubtless omitted, and $200 is probably a low enough figure to allow for the average equipment of this sort.

TABLE XIII. NUMBER OF MAJOR ITEMS OF PERSONAL PROPERTY FOUND ON 21 OHIO FARMS, WITH THE AVERAGE NUMBER OF EACH ITEM FOR ALL FARMS, AND FOR EACH FARM REPORTING THE ITEM, THE APPROXIMATE COST OF EACH ITEM, AND THE AVERAGE COST OF EACH ITEM FOR EACH OF THE 21 FARMS.

Name of Article	Number reported	No. of farms reporting	Av. No. per farm reporting	Av. No. per farm, all farms	Approximate cost or value	Total cost or value per farm, all farms
Horse—General purpose	6.0	3	2.0	0.29	$140.83	$ 40.24
Horse—Driving	17.0	10	1.7	0.81	104.12	84.29
Horse—Draft	73.0	18	4.06	3.48	145.82	506.90
Horse—Draft and brood	15.0	6	2 5	0.71	131.00	93.57
Colts	38.0	13	2.92	1.82	92.11	166.66
All horses	149.0	21	7.1	7.10	125.64	891.66
Double work harness	52.0	21	2.5	2.48	35.00	86.80
Single work harness	2.0	2	1.0	0.10	20.00	2.00
Double light harness	11.0	11	1.0	0.52	25.00	13.00
Single light harness	41.0	21	2.0	1.95	15.00	29.25
Bull	10.0	10	1.0	0.47	100.00	47.00
Milch cows	163.0	21	7.8	7.76	40.00	300.40
Young dairy stock	75.0	15	5.0	3.57	16.00	57.12
Beef steers	43.0	2	2.6	2.04	44.00	89.76
Young beef stock	40.0	4	10.0	1.90	18.00	34.20
Ram	21.0	8	2.6	1.00	10.00	10.00
Ewes—breeding	361.0	9	40.1	17.19	6.25	107.44
Wethers, etc.	482.0	4	120.5	22.90	3.50	80 15
Boar	8.0	9	0.9	3.80	15.00	5.70
Brood sow	90.0	15	6.0	4.28	14.00	59.92
Shoat	288.0	13	22.1	13.71	5.00	68.55
Pig	226.0	11	20.5	10.76	2.50	26.90
Hen	1768.0	21	84.2	84.19	0.55	46.30
Rooster	113.0	20	5.7	5.38	0.55	2.96
Other poultry	44.0	9	4.9	2.09	1.00	2.09

TABLE XIII. Continued.

Name of article	Number reported	No. of farms reporting	Av. No. per farm reporting	Av. No. per farm, all farms	Approximate cost or value	Total cost or value per farm, all farms
Bees (stand)	34.0	8	4.3	1.61	$ 2.50	$ 3.14
Walking plow	40.0	21	1.9	1.90	10.00	19.00
Sulky plow	4.0	4	1.0	0.19	35.00	6.65
Gang plow	6.0	6	1.0	0.28	65.00	18.20
Spike tooth harrow	27.0	21	1.3	1.29	15.00	19.35
Spring tooth harrow	7.0	6	1.2	0.33	16.00	5.28
Acme harrow	1.0	1	1.0	0.05	18.00	0.90
Disc or cutaway harrow	18.5	19	1.0	0.88	33.00	27.94
Roller or crusher	13.5	14	1.0	0.64	25.00	16.00
Planker	11.0	10	1.1	0.52	3.00	1.56
Weeder	14.0	15	0.9	0.66	10.00	6.60
Shovel plow	15.0	14	1.1	0.71	2.50	1.78
Manure spreader	11.5	13	0.9	0.54	125.00	67.50
Corn stalk cutter	1.0	1	1.0	0.05	25.00	1.25
Farm wagon and box	28.0	21	1.3	1.33	75.00	99.75
Truck or "handy" wagon	11.0	11	1.0	0.52	30.00	15.60
Spring wagon	11.0	10	1.1	0.52	75.00	39.00
Road cart	6.0	5	1.2	0.28	25.00	7.00
Hand cart	4.0	4	1.0	0.19	5.00	0.95
Carriage	14.0	13	1.1	0.66	100.00	66.00
Buggy	33.0	20	1.6	1.57	75.00	117.75
Sled	20.0	15	1.3	0.95	30.00	28.50
Cutter or sleigh	9.0	9	1.0	0.42	30.00	12.60
Road drag	3.0	3	1.0	0.14	3.00	0.42
Stone boat	15.0	10	1.5	0.71	2.00	1.42
Stock rack	5.0	4	1.3	0.23	10.00	2.30
Gravel or dump bed	3.0	3	1.0	0.14	6.00	0.84
Scraper or slip	3.0	3	1.0	0.14	5.00	0.70
Gasoline engine	5.0	5	1.0	0.23	200.00	23.00
Babcock tester	2.0	2	1.0	0.09	5.00	0.45
Aerator	1.0	1	1.0	0.05	5.00	0.25
Refrigerator	1.0	1	1.0	0.05	15.00	0.75
Cream separator	8.0	8	1.0	0.38	65.00	24.70
Combination churn	1.0	1	1.0	0.05	30.00	1.50
Corn planter—1 horse	3.0	3	1.0	0.14	18.00	2.52
Corn marker	6.0	6	1.0	0.28	2.00	0.56
Corn planter—2 horse	8.0	10	0.8	0.38	50.00	19.00
Cultivator—2 or 3 horse	30.0	17	1.8	1.43	28.00	40.04
Cultivator—1 horse	27.0	18	1.5	1.28	5.00	6.40
Corn binder	4.75	6	0.7	0.21	125.00	26.25
Sled harvester	2.0	2	1.0	0.09	25.00	2.25
Corn shocker	2.0	2	1.0	0.09	120.00	10.80
Corn shredder	0.6	2	0.3	0.03	175.00	5.25
Ensilage or fodder cutter	6.0	6	1.0	0.28	40.00	11.20
Corn sheller	14.0	13	1.1	0.66	6.00	3.96
Circular woodsaw	5.0	5	1.0	0.23	8.00	1.84
Grain binder	16.0	18	0.9	0.76	125.00	95.00
Grain drill	17.0	15	1.1	0.80	65.00	52.00
Fanning mill	11.5	12	1.0	0.54	25.00	13.50
Reaper	1.0	2	0.5	0.05	45.00	2.25
Hay loader	5.5	6	0.9	0.26	55.00	14.50
Mower	23.5	21	1.11	1.11	45.00	49.95
Hay rack	22.0	18	1.2	1.04	10.00	10.40
Hay rake—sulky	17.5	19	0.9	0.83	20.00	16.60
Hay rake—wooden	1.0	1	1.0	0.05	5.00	0.25
Wheelbarrow seeder	2.0	2	1.0	0.09	8.00	0.73
Tedder	9.5	10	1.0	0.45	38.00	17.10
Potato cutter	0.5	1	0.5	0.02	6.00	0.12
Potato planter	3.5	4	0.9	0.16	55.00	8.80
Potato sprayer	3.5	4	0.9	0.16	25.00	4.00
Potato plow (digger)	4.0	4	1.0	0.19	15.00	2.85
Potato digger	2.5	3	0.8	0.11	90.00	9.90
Potato sorter	2.0	2	1.0	0.09	20.00	1.80
Sap evaporator	6.0	6	1.0	0.28	100.00	28.00
Sap gathering tank	4.0	4	1.0	0.19	8.00	1.52
Sap storage tank	8.0	5	1.6	0.38	12.00	4.56
Sap sled	3.0	3	1.0	0.14	3.00	0.42
Orchard sprayer	5.0	6	0.8	0.23	20.00	4.60
Cider mill	3.0	3	1.0	0.14	10.00	1.40
Fertilizer spreader	1.5	2	0.8	0.07	25.00	1.75
Feed grinder	3.0	4	0.8	0.14	40.00	5.60
Fruit evaporator	2.0	2	1.0	0.09	50.00	4.50
Litter carrier	1.0	1	1.0	0.05	30.00	1.50
Beet cutter	1.0	1	1.0	0.05	25.00	1.25
Beet lifter	1.0	1	1.0	0.05	15.00	0.75
Tread power	1.0	1	1.0	0.05	40.00	2.00
Incubator	4.0	3	1.3	0.19	10.00	1.90
Brooder	2.0	2	1.0	0.09	7.00	0.63

The prices for harness, machinery, etc., in Table XIII are, as nearly as can be ascertained, the usual retail prices prevailing in Ohio for new articles. Both farmers and merchants were consulted in the effort to obtain these figures, but of course they are merely suggestive. The first values shown later in Table XIV include both first and second hand prices and may be regarded as indicative of the usual farm practice.

In making up a list of machinery for the average farm there are so many factors to be taken into consideration that a generalization would be of little value. The number of any single item reported for all the farms, the average for all farms, the percentage of farms reporting the article, and the number of articles per farm reporting are all to be regarded as useful in separating the necessary items from those only occasionally or rarely used. A careful study of the first four columns in Table XIII is recommended as of more value than a suggested list, especially with the major items of equipment shown in this table. For the purpose of this study it is desired only to obtain an average figure for the total first cost of machinery and tools, hence the average number of each item on the 21 farms is multiplied by the usual cost and the total secured in this way.

TOTAL COST OF EQUIPPING THE FARM

From the foregoing discussion it will be possible to make a summary, showing more or less accurately the first cost of equipping the "average farm" under consideration. In the case of livestock and produce, supplies, etc., the actual inventory valuations are taken from Table VII rather than approximations which might be obtained from Table XIII.

The total would be as follows:

Land, 165.88 acres at $46.25 (average)	$ 7,676.42
Farm buildings	2,700.00
Household buildings	2,500.00
Fences	763.74
Drainage	366.43
Water Supply	225.00
Work Animals	640.71
Colts and driving horses	250.95
Cattle	582.26
Sheep	201.05
Swine	158.34
Poultry	52.60
Bees	3.23
Harness	131.05
Machinery	1,125.48
Minor articles	200.00
Produce, supplies, etc	631.93
Total	$18,209.19

As the practice in housing poultry on the average farm is bad, this figure might be slightly increased, although much more desirable poultry houses might be constructed as economically as the average ones used.

Total value of real estate	$14,231.59
Total value of personal property	3,977.60
Percentage invested in real estate	78.15
Percentage invested in personal property	21.85

In actual practice innumerable factors enter in to reduce the cost of equipping farms. Few farms in the older sections of the United States like Ohio are equipped outright with new buildings, fences and machinery, and the summary just given would, of course, apply only in these few cases. It is interesting, however, in showing the amount of money which can be spent over a course of years in bringing the equipment up to a profitable working basis. The 21 farms studied in such detail are not in any sense exceptional or "model" farms. They represent a large class, probably more successful than the average, and no doubt the detailed estimates of their average equipment cost will be found helpful, as a guide to planning the proper distribution of capital.

UNIT EQUIPMENT COSTS

The third phase of this study was made less prominent than the two already discussed. This phase is that of current equipment charges on farm operations, including machinery costs per acre of crop, building charges per head of livestock, and storage or building charges per unit of products. From the circulars sent out to the Ohio corn growers, from Mr. Thompson's notes and from the inventories on the farms of cooperators, have been gathered considerable data regarding the machinery costs, but the determination of annual and unit costs of buildings, fences, etc., has not been attempted because of the meager information at hand.

That there is a distinct cost each year for buildings, fences and other improvements is undisputed, but the exact amount is difficult to ascertain, owing to the lack of information concerning the rate of depreciation on such equipment. The depreciation on the modern steel wire fences is rapid, and often excessive, while many of the old rail, wire and picket fences are in good condition after years of service. The ordinary farm usually has from three to ten kinds of fence, hence the securing of data of this sort was found to be too complex for the present study. Building depreciation varies with the construction and subsequent care, as well as with the use to which different structures are put. The increase in the cost of construction during the last generation has equalled

if not exceeded the depreciation from the original value, hence the determination of interest and depreciation involves more study than could be given at this time. The annual deterioration in condition is probably from 2 to 5 percent of the original standard in case of buildings, and from 6 to 20 percent in case of fences. If no change occurs in the cost of construction, the annual depreciation, repair and interest charges could be added and the total charge apportioned to the various units, but further investigation is necessary before averages can be presented in this connection.

Regarding machinery costs the problem is simpler. Prices have not changed so materially, the annual rate of depreciation is more easily obtained, and the amount of use each year more easily reduced to a unit basis. Table XIV shows in detail the data on machinery costs, either on the annual or acre basis. The number of machines included in the final average is shown in the first column. In many cases there were unit costs which were clearly out of the usual range of probability, and these were discarded in taking the average. The first value at time of purchase by the farmer reporting is shown, this average including many second-hand machines. The "second value" is the inventory rather than the sale value. The average investment is obtained by averaging the first value and the value at the beginning of the last season. The latter is obtained by adding to the value at the close of the last season, as shown by the inventory, the average depreciation. This method produces the same result as would be obtained by assuming that the rate of depreciation were constant throughout the period of use of the machine up to date and averaging the values at the beginning of each season. The method involves a slight possibility of error, due to the fact that the repairs are not put on at a constant annual rate, and the actual difference in inventory would be somewhat affected. The discrepancy would be negligible. The average years in use up to the last date of inventory is shown, and from this and the difference between the first and second values, the annual rate and percentage of depreciation are obtained, the percentage being based on the first value. The repairs per year are from actual records or careful estimates. The interest is calculated at five percent on the average investment. The annual cost is the sum of depreciation, repairs and interest. The lowest and highest acre costs for different machines are shown, though these are not always included in the average. The lowest figure is usually for a second-hand machine used on a large acreage or for a long period, while the largest is usually for a new machine given very little use. Extra machines on any farm show a much higher cost than those in ordinary use. The interest charge is the greatest factor in the

cost of little used machinery, emphasizing the advantage of utilizing machines to their maximum capacity. All data in Table XIV are averages of the entire group and not a mean between individual costs.

The wide variation in acre cost of all machinery suggests the necessity for considering the acreage per year as an extremely important factor. For instance, sixty corn planters averaged 50.1 acres per year at an acre cost of 8.1 cents; 24, averaging 63 acres, cost between 4 and 8 cents per acre; and 15, averaging 34 acres, cost from 10 to 13 cents per acre. This separation of planters into two groups was suggested by the appearance of curves plotted to show the frequency of different acre costs for all the machines. Extremely high costs in a few cases were sufficient to raise the averages considerably above the cost occuring most frequently. The curve of planter costs showed two distinct groups, with the average midway between. It is evident that machinery costs should be studied for different acreages, especially since the annual cost of the same machine on different farms varies much less widely than the acre costs.

Only 9 out of 130 walking plows cost over 20 cents per acre and these were excluded from the average. The question of plow costs in the "hill section" was raised. Twenty plows in this section showed an average of 6.1 cents per acre and a mean of individual costs of 7.2 cents. The first value was $13.20; second value, $6.80; average investment, $10.40; years used, 9.15; annual depreciation, 71 cents; percentage of depreciation, 5.3; acres per year, 26.3. The uniformity of these figures with the average for the whole number was surprising, especially in view of the low percentage of crop area in case of many farms in this section.

The cost shown for cultivators, harrows, rollers, plankers and weeders is on the basis of one acre covered once, or the "acre time.' Since in the tillage of an acre of land the same implement may be used a varying number of times the acre time is considered a more logical unit than the acre. One spring tooth harrow covering a total of 250 acres per year at 0.7 cents per acre time and one covering 10 acres per year at 17 cents per acre time are omitted from the average. The roller operating at 0.4 cents per acre time was used 300 acre times per year. Excluding this one, the cost per acre time was 2.4 cents. About 4-5 of the rollers cost between 0.5 and 5 cents per acre time. The wooden planker, drag, or float, as it is variously called, is usually home-made, hence the low first cost. Many home-made wooden rollers are also found. Weeders range rather uniformly from 2 to 12 cents per acre time. One, which covered the equivalent of 300 acre times per year at a cost of 0.3 cent was omitted from the average.

Kind of machine	No.	First value	Second value	Average investment	Years in use	Depreciation		Repairs per year	Interest per year	Total cost per year	Acres worked per year	Acre cost		
						Per year	Per cent					Low	High	Average
Walking plow	115	$ 13.60	$ 6.95	$ 10.62	9.6	$ .69	5.1	$0.71	$0.53	$ 1.93	27.1	$ 0.018	$ 0 359	$ 0.072
Riding or gang plow	42	47.22	33.05	40.17	5.6	2.54	5.4	0.96	2.01	5.25	28.8	0.017	0 42	0.183
Harrow, spike	74	12.47	6.83	9.99	8.3	0.68	5.5	0.29	0.50	1.47	79.2	0.005	0.108	0.019
Harrow, spring	16	17.00	7.72	12.88	9.0	1.03	6.0	0.21	0.64	1 89	38.8	0.009	0.17	0 027
Harrow, disc	62	26.90	14.93	21.62	7.4	1.62	6.0	0.27	1.08	2.97	60.4	0 005	0.317	0.049
Roller	23	22.50	14.09	18.67	11.3	0 75	3.3	0.03	0.93	1.71	84.2	0.004	0.092	0.02
Planker or drag	13	2.94	1.42	2.30	6.5	0.24	8.0	....	0.11	0.35	45.4	0.002	0.035	0.008
Weeder	19	10.79	5.76	8.29	7.2	0.70	6.5	....	0.41	1.11	34.4	0.013	0.173	0.033
Manure spreader	46	112.25	82.93	102.24	3.2	9.30	8.3	1.58	5.11	16.29	....	* 7.81	*49.38	*16.29
Corn planter	60	35.45	18.29	27.97	7.8	2.20	6.2	0.47	1.40	4.07	50.1	0.02	0.299	0.081
Cultivator, 1 horse	12	4.79	2.58	3.81	8.5	0.26	6.3	0.07	0.19	0.52	12.1	0.018	0.068	0.043
Cultivator, 2 or 3 horse	102	24.51	12.00	19.04	7.9	1.57	6.3	0.34	0.95	2.86	69.7	0.009	0.418	0.041
Corn binder	28	105.32	51.78	82.79	6.3	8.48	8.0	1.60	4.14	14.26	38.5	0.199	2.22	0.369
Corn shocker	6	120.83	69.17	101 46	4.0	12.92	10.7	0.79	5.07	18.78	22.3	0.248	2.78	0.842
Grain binder	24	117.11	46.96	86.10	8.6	8.13	7.0	1.10	4.31	13.54	51.1	0 128	0.688	0 264
Grain drill	40	59.69	35.35	48.75	8.7	2.81	4.7	0.33	2.44	5.58	43.0	0.018	0.397	0.13
Fanning mill	11	20.81	13.72	17.64	9.3	0.76	3.7	....	0.88	1.64	....	* 0.41	* 2.58	* 1.64
Hay loader	12	57.75	30.29	45.76	7.9	3.47	6.0	0.65	2.89	7.01	28.3	0.13	0.488	0.248
Mowing machine	45	41.64	21.67	32.94	7.8	2.56	6.1	0.93	1.65	5.14	49.1	0.04	0 558	0.105
Hay rake	35	19.21	9.86	15.09	8.5	1.11	5.8	0.26	0.75	2.12	38.8	0.005	0.347	0.055
Hay tedder	20	31.70	18.60	25.96	8.0	1.63	5.2	0.40	1.30	3.73	22.5	0.015	0.427	0.164
Wagon	76	62.72	28.26	46.99	11.5	3.00	4.8	1.20	2.35	6.55	....	* 1.23	*11.21	* 6.55
Corn shredder	5	474.30	344.80	431.14	3.0	43.17	9.1	0.98	21.56	65.71	....	*37.25	*84.50	*65.71
Ensilage cutter	11	111.04	71.36	94.36	6.3	6.32	5.7	0.83	4.72	11.87	....	* 2.21	*36 80	*11.87
Corn sheller	11	9.74	5.34	7.73	11.5	0.38	3.9	0.04	0.39	0.81	....	* 0.22	* 2.26	* 0.81

*Annual cost

No records are at hand as to the acres covered by many of the manure spreaders, and of course the cost of fanning mills, wagons, corn shredders, ensilage cutters and corn shellers can not well be reduced without difficulty to an acre basis. Annual costs are given in these cases. The mean acre cost of 12 spreaders was 87 cents, and the mean cost (or machinery charge) per load for 12 other spreaders was 5.9 cents. It is interesting to note that the average years in use for spreaders is much lower than that of most machines. The majority of spreaders in use are probably innovations on the various farms, hence the cost data are more difficult to secure than those for machines introduced earlier.

Excluding second-hand implements, the cost per acre time for one-horse cultivators ranges from 2.6 to 6.8 cents, with the greater number between 4 and 5 cents. A few three-horse (double row) cultivators are included with the two horse. Only 3 of the 2- or 3-horse cultivators cost over 13 cents per acre time. One of these was an extra cultivator, bought second-hand and used on only 15 acres in 4 years. The bulk of cases ranged between 1 and 10 cents per acre time, 35 out of 102 being between 2 and 4 cents, 24 between 4 and 6 cents, and 12 below 2 cents.

The acre cost of corn binders varies greatly, but in about half the cases was between 25 and 45 cents per acre. Two sled harvesters cost less than 10 cents per acre. The corn shockers reported were used on a much lower acreage than the corn binders, with a much higher acre cost. The wide variation in size and first cost of ensilage cutters makes the average of doubtful value. Two cutters cut about 120 tons each per year at costs of about 7 cents per ton, while another cut about 1,250 tons per year at a cost of 2.9 cents per ton. Three two-hole corn shellers had a mean cost of $2.01 per year, while 7 out of 8 one-hole shellers cost less than 60 cents per year. The few years in use undoubtedly account for the remarkably low repair cost in the case of the corn shredder. Fourteen grain binders cost between 15 and 30 cents per acre. Grain drills ranged very uniformly between annual costs of about $1 and $10, and acre costs of from 6 to 20 cents.

The acre cost of mowing machines varied uniformly between 4 and 18 cents, 35 out of 45 machines being within these limits. The annual cost of 20 out of 35 hay rakes was between $1 and $2.50.

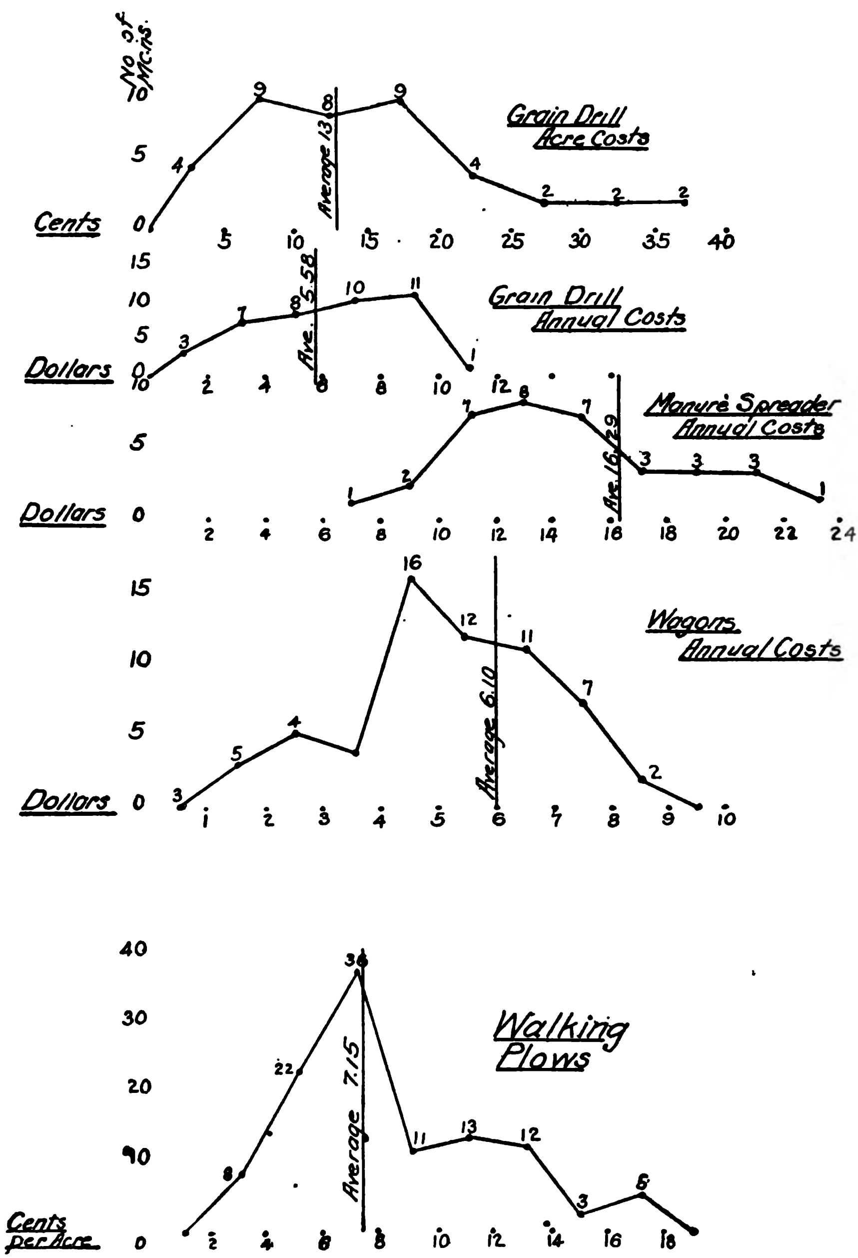


Fig. 3. Showing frequency of acre and annual costs of different farm implements.

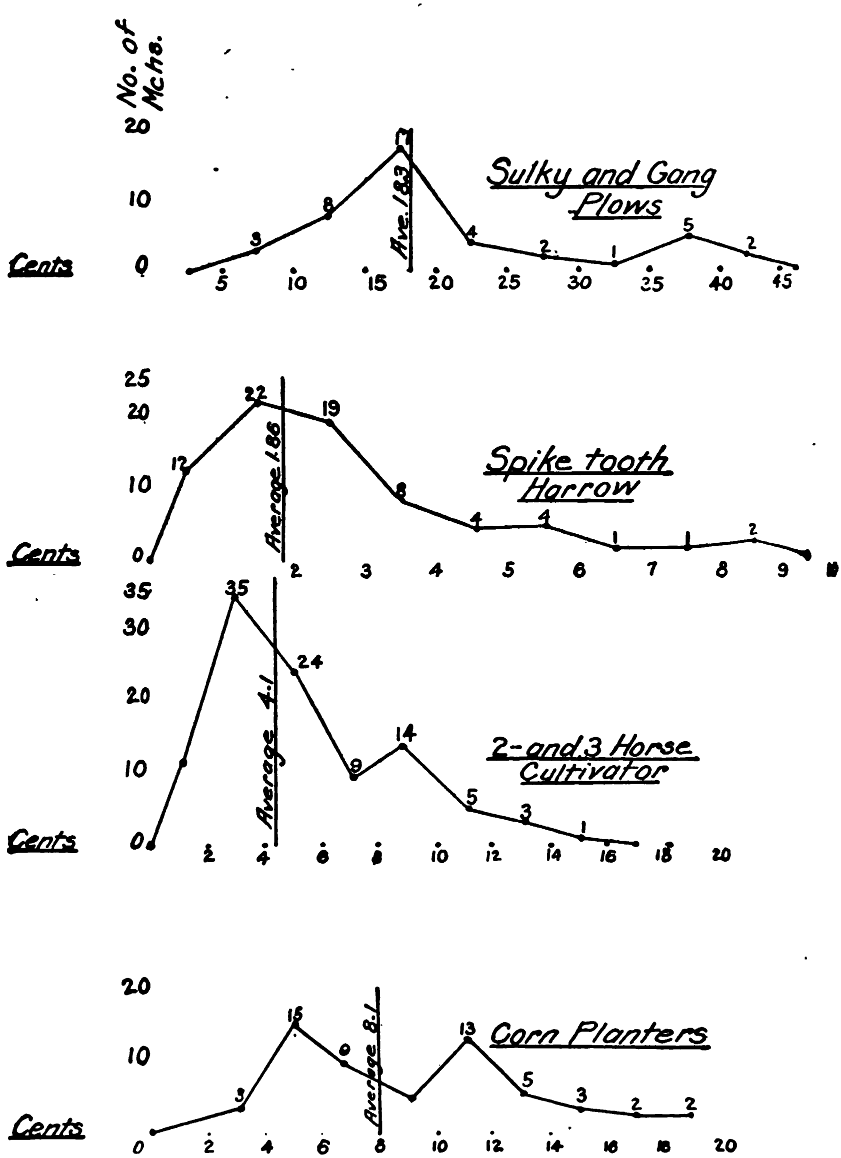


Fig. 4. Showing frequency of acre and annual costs of different farm implements

The cost of these 20 rakes ranged from 2.4 to 16.8 cents per acre time, with a mean of 7.3 cents. This is probably a better figure than the average (5.5 cents) give in Table XIV. In the latter are included a number of revolving wooden rakes and second-hand steel rakes at a cost of 0.5 to 2.5 cents per acre, and two side-delivery rakes at 17.1 and 29.4 cents, respectively. Thirteen out of 20 hay tedders cost between 15 and 25 cents per acre. The lowest figure is for a second-hand machine and the highest for a machine tedding an average of 5 acres per year. The lowest annual wagon costs are due to truck, or "handy" wagons and to those not purchased new. Sixty percent of wagon costs are between $4 and $8 per year.

Figures 3 and 4 give diagrams to illustrate the frequency of various acre and annual costs for different machines. The height of the points on each curve indicates the relative number of machines with costs within the range indicated by the figures on the base line. Of walking plows, for instance, 8 cost between 2 and 4 cents per acre, 22 between 4 and 6 cents, and so on. The average cost for the entire group is shown. Usually it is higher than the acre or annual costs which are most frequent, owing to the influence of abnormally high costs. Where the latter were widely separated from the others, as in the case of one manure spreader with an annual cost of $49.38 and 3 wagons costing over $11 per year, they are not shown on the diagram. The curves show, more clearly than the average, the cost of the greater number of machines, but the average is valuable because of the consideration given to the most and least as well as the normally expensive ones.

While the lack of numbers makes the data suggestive rather than conclusive, they present a fair basis for estimates of the machinery cost of producing crops.

SUMMARY

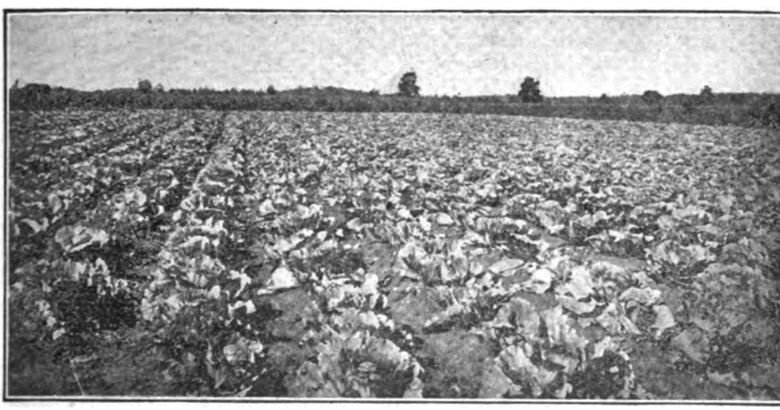
Proper organization is prerequisite to successful farm management. Proper organization refers not only to the cropping system, ive stock management, etc., but to the distribution of capital and he selection of equipment. This study of a number of Ohio farms does not afford sufficient data from which to draw general conclusions, but illustrates by concrete example many of the factors to be aken into consideration in equipping farms. Further study along the lines indicated should provide data of great value to the farm manger. This outline of some of the economic problems involved in he equipment of farms is presented as worthy of the attention of tudents of farm management and of farm economics in general.

TWO RECENT IMPORTANT CABBAGE DISEASES OF OHIO

OHIO Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., MARCH, 1911.

BULLETIN 228



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CONTENT

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 228 — MARCH, 1911

TWO RECENT IMPORTANT CABBAGE DISEASES OF OHIO

By THOS. F. MANNS

INTRODUCTION

Many areas in Ohio have soils which are well adapted to trucking crops or other lines of intensive culture. The number of large cities, together with excellent shipping facilities, greatly stimulates such enterprises. As a rule these districts, when carefully managed, have paid the investors good returns upon their investments. Too often, however, the history of the districts exploited for certain intensive cropping, with their manufacturing plants for utilizing the products, has been that of final failure. Under intensive culture, where large profits are apparently assured, the tendency is to select the better part of the farm, keep it abundantly fertilized, and practice close or continuous, one-crop culture.

ONE-CROP CULTURE OFTEN FATAL

There are but few of our many crops which may be grown successively on the same area without sooner or later bringing about soil sickness by the introduction of many persistent fungus and insect enemies. Fig. 1 shows a field cropped for the first time with cabbage—18 percent sick with "yellows"—Fusarium wilt; 6 percent sick with "black-leg"—Phoma wilt. Among the very few crops which partially withstand successive cropping, corn probably suffers the least. Aside from the probability of causing "soil sickness", other good reasons may be mentioned why the one-crop culture should be little practiced; among these is the cost and difficulty of maintaining a balanced food supply. Like the proverbial chain which is no stronger than its weakest link, a soil in no wise can produce a larger yield of a particular crop than is made possible by the total available amount of a certain plant food low in that soil. For example, a soil, in which the possible potash availability is sufficient to produce only 50 percent of a cabbage crop, will be limited to but half a crop, no matter how much money may be expended for other fertilizing elements.

The one-crop culture makes heavy demands upon certain plant foods, e. g., cabbage in its needs for potash. On the other hand a proper rotation distributes these demands and allows of longer periods for making available the necessary elements. Hence, the rotation is more likely to have ready the required plant foods, than is the one-crop culture.

Also, there are good reasons why cultivated crops, such as corn, potatoes, cabbage, beans, beets, onions, etc., should be made a part of a rotation rather than otherwise, because of the opportunity the extra cultivation affords of incorporating organic materials (manures, etc.) into the soil, and of leaving the soil in a better tilth.

After the important features of proper rotation and fertility maintenance have been worked out, probably the next in order is the

IMPORTANCE OF SEED AND THE SEED BED

The object of this bulletin is to call the attention of cabbage growers in particular, and truck growers in general, to the possible means of avoiding or preventing the further spread of certain fungus parasites which may, and do, exist as persistent soil troubles.

Fig. 1. Showing a field cropped for the first time with cabbage. 18 percent sick with "yellows" (Fusarium wilt). 6 percent sick with "black-leg" (Phoma wilt). The diseases present were transferred directly from the seedbed.

Great progress has been made during the past twenty years in the knowledge of plant diseases, their modes of infestation, their means of continuing from season to season, and their manner of distribution. As a rule, there are usually loop-holes in the life history of parasites through which economic control is possible. As in the old adage, however, "an ounce of prevention", etc., is playing a far more important part in the control of plant diseases than is treatment after the disease becomes active.

Among the annual crops, as far as the possible introduction of persistent fungus soil troubles is concerned, an insight into the seed and seed bed is often of first importance. Is the seed carrying the specific fungus trouble? If so, is there a seed treatment that will destroy the spores of the disease? Second, is the soil already infested where the seed is to be planted? Often a knowledge of these facts, when properly applied, makes the difference between success and failure. "Experience", certainly, "is a dear teacher," when through this process we learn that after a certain plant disease has gained a foot-hold in our fields, it means we must drop from cultivation, for a decade or more, a crop which previously has been a money maker. This is exactly what the Fusarium wilt ("yellows") of cabbage in our soils signifies.

HISTORY AND EXTENT OF CABBAGE CULTURE IN OHIO

Cabbage in Ohio has been grown by market gardeners in the vicinities of the larger cities for a long time. Only within the past twenty-five years has there been a tendency among farmers in certain districts to make this an extensive crop. Much difficulty is encountered in obtaining accurate data on the extent and value of the cabbage crop, as owing to its minor importance no statistics have been taken.

One of the largest cabbage districts includes the vicinities of Clyde, Greenspring, Fremont and Bellevue, (Seneca and Sandusky counties) where the kraut industry is quite extensive. Three factories are located at Clyde, and one each at the other towns mentioned. All these factories have sprung up within the past twenty years; several within the last eight or ten years.

With the exception of a few carloads of cabbage which are purchased by outside buyers and shipped to Cleveland or other large cities for direct consumption, the large bulk grown in this district is made into kraut. It is estimated that between 3,000 and 4,000 acres are annually put to cabbage. The average annual yield varies from six to nine tons per acre. The price fluctuates considerably, that is, from $5 to $12 per ton, with an average of about $6. Under favorable conditions an average yield of twelve tons may quite readily be reached. Many of the growers maintain that a cabbage crop of 9 tons per acre is a better paying crop than corn, wheat or oats under fair yields.

During the past few years, considerable stimulus has been given the growing of cabbage, through the kraut factories previously mentioned, offering to contract at fair prices all the cabbage grown.

There is always a good demand in the large cities in late summer and early fall for cabbage. It is very difficult to get data of the acreage, yield and average value of the crop grown by those who cater to these demands. The prices vary greatly according to the season and the location. The price per ton, as indicated by fifteen correspondents catering to city trade, varies from $8 to $20. The total acreage devoted to cabbage in Ohio probably does not exceed 8,000 to 10,000 acres. This area, however, represents a value sufficient to demand statistics.

CABBAGE IN OHIO A SHORT-LIVED CROP

The history of cabbage culture in the several districts of the state points to the crop as being very short lived. Some of the quickly lowered yields have resulted from rapid soil exhaustion. Few of the growers realize that 15 tons of cabbage per acre removes from the soil three times the quantity of plant food (nitrogen, phosphoric acid and potash) required for a crop of 20 bushels of wheat. This factor, however, has been secondary in shortening the life of the crop. The chief cause of failure has been the introduction and spread of several severe cabbage diseases. Chief among these heretofore, appears to have been the brown or black-rot. Quite recently, however, two apparently new troubles have made their appearance. These latter have become very active and disastrous in the districts about Clyde and Greenspring. In the newer cabbage districts of Fremont, and the outlying areas some distance from Clyde, Greenspring and Bellevue, these diseases have made their appearance, though to a limited extent. The preliminary method of distribution, viz., through infested seed beds, would seem to offer means of partial control. The chief object of this bulletin is to acquaint growers with these cabbage troubles, point out their manner of distribution, and call attention to practices which will aid in their elimination or control.

CABBAGE DISEASES—THEIR DISSEMINATION AND CONTROL

There are four diseases in the state which are very active in reducing the cabbage crop. These are (1) Brown or Black-Rot, a bacterial disease, (2) Club-Root, a slime mold disease, (3) Fusarium Wilt, known also as "yellows", a fungus disease, and (4) Black-Leg or Foot-Rot, known also as a wilt, and likewise a fungus trouble.

The two first named diseases have been known throughout the state for a number of years and their severity is fully apprehended. The two latter named troubles, which apparently have been active

with us for some six years or more, have but recently been studied at this Station. It is quite beyond us to tell why certain organisms should have adapted themselves to a life of parasitism. But, on the other hand, it is usually not difficult to discover the means of dissemination. Of the four above-mentioned diseases there is no evidence whatever that any one is carried internally in the seed (within the seed coat) and the possibility of such being the case is far remote. There is no reason, however, why the seed may not externally carry the spores or fruiting bodies of, at least, the three last named of the above diseases. From examinations of washings of fifteen samples of seed, by aid of the centrifuge and microscope, no evidence was found indicating that externally the seed was carrying disease; yet, in order to eliminate the possibility of disease reaching the seed.bed in this manner, the writer advises *the treatment* of all seed just previous to sowing. Soak the seed twenty minutes in a solution of one part formaldehyde in 320 parts of water* (1 oz. of 40 percent formaldehyde in 2 1-2 gallons of water). The cost is practically nothing. The treatment eliminates the possibility of the seed carrying disease, while, on the other hand, it is beneficial rather than injurious to the seed. This advice is given, looking toward entire prevention of these diseases getting a foothold in the seed beds. *Under no circumstances should the seed bed be located on an area on which cabbage has recently been grown*, nor upon land that at any time has been known to have had sick plants upon it. The seed bed should be located at a considerable distance from buildings near which cabbage has been hauled, stored, or the refuse parts fed.

It is now known that all four of the diseases named on page 258 are caused by parasites, which in themselves are more or less persistent soil organisms. Their introduction into non-infested fields or localities may and does come about through one or several of the following ways:

1 Through the seeds carrying the spores of the disease on their surface.

2 Through shipment of cabbages, celery, onions, potatoes and other truck crops carrying the disease from cabbage-sick districts; the wastes of these products finally reaching gardens or fields which later are used as seed beds for cabbage.

3 Through transfer of seedling cabbage and celery grown on cabbage-sick soil.

4 Through manures in which diseased cabbage material has been thrown, or carried on the feet of men, of work animals or of other stock.

*Experiments conducted August 23, 1910, and following show that cabbage seed will stand heavy treatment with formaldehyde.

5 Through machines, plows, drags, cultivators, etc., being taken from sick fields to those not infested.

6 Through transferring the disease in handling seedlings, making infection possible by bruising, or the breaking of the leaves.

7 Through insects, such as the adults of the cabbage or radish maggots, lice, and others. Especially does this seem true of the Black or Brown Rot of cabbage, a bacterial disease, and the black-leg.*

8 Through wind and running water.

GENERAL TREATMENT

Having enumerated above the ways in which these diseases are likely to be disseminated, the next question is, what measures may be used in their control? In new localities adapted to cabbage, and areas distant from infested localities, the problem is not a difficult one. Treatment of seed previous to planting should be practiced. In nowise should cabbage, cauliflower or celery seedlings be purchased unless known to have been grown on soil free from cabbage diseases. Care should be taken to see that no manures are used containing cabbage or other truck crop litter. The seed bed should always be placed on a new and somewhat distant area each year. A satisfactory rotation should be practiced, for example: wheat, clover, cabbage and corn; the second crop of clover to be left and the sod to receive 15 to 20 tons of manure; this to be supplemented, at the time of preparation, by an application of 300 to 600 lbs. of a first grade, complete fertilizer high in potash. Two to four hundred pounds of common salt is also recommended. The lime content of a cabbage field should always be kept high. In case manure cannot be obtained, the turning under of a clover crop, supplemented by 700 to 900 lbs. of a complete fertilizer high in potash is to be recommended. Where commercial fertilizer, alone, is to be relied upon, fully 2000 lbs. of a mixture of 400 pounds each of nitrate of soda and muriate of potash with 1200 pounds of acid phosphate should be used if a maximum crop is to be expected.

WHAT TO DO IN AREAS ALREADY INFESTED

Too much emphasis cannot be placed upon the persistent nature of these organisms when once placed in the soil. Though no complete data are to be found indicating the length of time any one of these organisms may persist in the soil without the intervention of a cabbage crop, the evidence is quite sufficient to show

*In the following references, insects have been recognized as agents in the distribution of diseases.

[1]Smith, Erwin F., The Black Rot of the Cabbage, Farmers' Bulletin 68: 1898 U. S. D. A.

[2]Zeitschrift fur Pflanzenkrankheiten, 16: 257-276; 1906, "Krebstrünke" and "Fallsucht" bei den Kohlpflanzen, verursacht von *Phoma oleracea* Sacc., by Prof. J. Ritzema Bos. (Wageningen.)

[3]Zeitschrift fur Pflanzenkrankheiten, 17: 258-267, 1907. Neue Kohlkrankheiten in Nord Holland, by Dr. H. M. Quanjer, (Wageningen.)

that six to eight years will not be adequate to remove the organism of the Fusarium wilt. In the case of the other troubles, they may not be quite so persistent; this much is true nevertheless, proper rotations, in which are included grass or grain crops, are the only means known at present to remove these diseases from the soil. A partial exception should be made in the use of lime for the prevention of club-root. There are always to be found, in cabbage-sick districts, some fields which have not yet become infested. Only through the greatest precautions can such fields be kept from becoming diseased. The seed beds must be kept free from disease. Two or more seed beds in different places may be started, and plants only from the healthiest be used. Tools, machinery and animals should not be taken directly from infested fields to those not infested, as this will be a sure way of distributing disease. The cleaning of implements after use in infested fields should be practiced. Cattle, sheep or other stock should not be allowed to pasture promiscuously from infested to non-infested fields. In no wise should manure containing cabbage litter, or made by animals running over sick fields, be used on non-infested areas. These precautions may seem rather severe, but the writer's experience with the distribution of flax-wilt (a Fusarium disease) in the north-western states has emphasized the old adage, "Eternal vigilance is the price of clean land." In this respect, a persistent soil disease should be regarded as even more disastrous than a noxious weed; the latter may be uprooted, while the former requires 4 to 10 years or more of systematic cropping for its elimination.

Some knowledge of each of these specific diseases is required in order to practice the most effective methods for their control and prevention. In the description given below of each of the particular troubles, further precautions or recommendations are given, which apply to each disease specifically. In case of doubt as to methods of procedure, or as to identification of the trouble, the experience of the Department of Botany at the Experiment Station should be called into service.

WILT, FUSARIUM WILT OR YELLOWS OF CABBAGE

Fusarium sp.

This disease has been known in the eastern cabbage districts for some time, though little has been done upon it by scientific workers. Recently Mr. L. L. Harter[4], of the United States Department of Agriculture, has published in *Science* results of infection and other experiments in which the causative organism is shown to be a fungus of the genus Fusarium. Dr. E. F. Smith first called attention to this trouble in 1895.

We have experienced no difficulty in obtaining the Fusarium parasite from the sick plants. In infected seedlings or the early stages of the disease more success is met with in securing cultures free from contamination (See Figs. 13 and 14, p. 274). Cabbage specimens from a number of fields in the vicinity of Clyde, Sandusky county, have yielded the fungus. The other localities from which infected plants (giving the organism in cultures) have been obtained, are Greenspring, Seneca county; Fremont, Sandusky county; Englewood, Montgomery county, and Armenia, Washington county. The disease has also been reported from St. Bernard, Hamilton county; Waynesburg, Stark county; Orrville, Wayne county; Lodi, Medina county, and Newark, Licking county.

This disease has not been reported in Europe to the writer's knowledge.

The severity of the disease in the vicinity of Clyde and Greenspring makes it imperative that precautions be taken at once to check its distribution, or the cabbage industry will soon be one of history so far as these vicinities are concerned.

For just how many years this disease has been active in these localities is hard to determine. By inquiry among the more observing of those who have grown cabbage a number of years, the evidence seems sufficient to indicate that for six to eight years the trouble has been making considerable headway in decreasing the yields. The persistent nature of the organism as a soil trouble further indicates that six to eight years of other than cabbage cropping is not sufficient time to remove it. In other words, a field which has become thoroughly sick with this disease will not again be capable of producing a healthy or satisfactory crop of cabbage in six to eight years. Other crops, excepting, possibly, cauliflower, mustard and related plants, will do well upon cabbage-sick land. The length of time required to remove this organism from the soil has not been determined. With heavy manuring and tilled

[4]Science N. Ser. 30: No. 782, p. 934, 1909.

crops, probably fifteen years will not do it. With much grass and grain cropping, probably ten years will suffice. Permanent grass pasture will do the work in the shortest time.

LOSSES FROM THE FUSARIUM WILT

The severity of the disease depends wholly upon the amount of soil and seed bed infestation. Usually in new fields, when the seed bed is but lightly infested, the losses the first season seldom reach higher than 2 to 5 percent. However, should the seed bed be badly infested, sometimes 50 percent of the plants wilt within a week or ten days following the transplanting. Where fields have become badly infested, the injury may reach 95 percent or even total loss. (See Fig. 2, showing part of a 10-acre field in which the cabbage was so sick the owner had ceased cultivating, and was allowing grass and weeds to take the field. The yellowing of the foliage together with the dropping of leaves are characteristic of the Fusarium wilt. The loss in this field was practically total. Fig. 3 illustrates a field carefully cultivated, though 75 percent of the plants were already down, Aug. 4, 1910).

Losses of from 50 to 80 percent are to be seen in the older and badly infested fields. The rapid progress of the disease in badly diseased areas is exceedingly discouraging to growers. One field, which had not previously been in cabbage for eight years, showed marked symptoms of sickness, and a loss of 30 percent was estimated. Much of this sickness appeared to be carried over from the crop of eight years before.

SYMPTOMS OF THE DISEASE

This trouble in the vicinity of Clyde is known as "yellows"—this term being applied because of the external appearances. In diagnosing the disease, this color characteristic is the first symptom to be relied upon. Later, a stunted growth, with a tendency of the lower leaves to drop at the lightest touch is further evidence of the disease. To the keen observer these symptoms may be detected in the seed bed previous to transplanting (See Figs. 9 and 10, pp. 270 and 271). In these early stages, the fungus responsible for the disease may be taken out in pure culture by artificial media. Later, bacterial contamination takes place. (See Figs. 13 and 14, p. 274.) Plants which show the symptoms in the seed bed, upon being transplanted, make no further growth, they simply wilt, turn black, and the lower leaves usually fall off.

After setting out, the healthy plants are attacked at all stages of their growth. In the older and later infected plants, the preliminary symptoms are similar to those in seedlings; yellowing of the lower and outer leaves takes place; these leaves later drop, turning a drab color, the lowest first, being followed successively at different times by others in their order (See Fig. 4, p. 265).

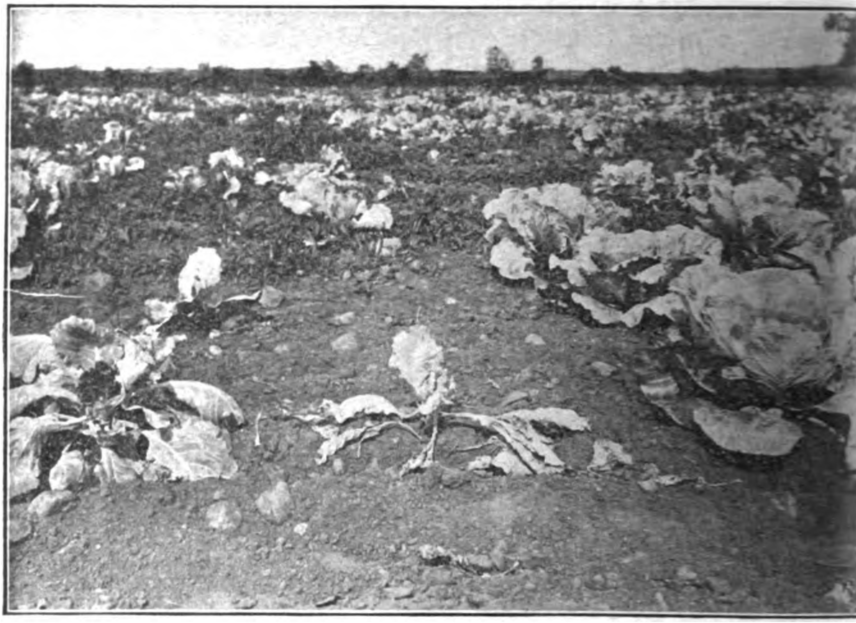

Fig. 2. The plants at the center and left are infested with the Fusarium disease. Note how the leaves have wilted and dropped from the plant at the center.

Fig. 3. Note the two plants in the center and left foreground that have died with P[illegible] "black leg" disease. Fully 75 percent of the plants had wilted from "black-leg" and "[illegible]" previous to photographing.

Photographed August 4, 1910, Clyde, [illegible]

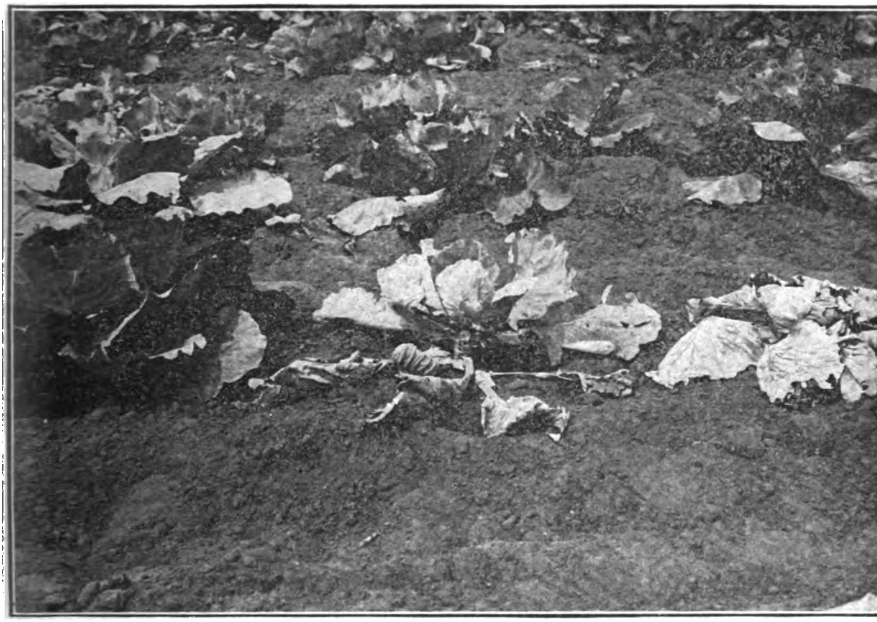

Fig. 4. Showing the difference between the work of the Fusarium Wilt (yellows), plant at center and the Phoma wilt (black leg), plant at right. A complete collar rot had taken place in the latter plant.

In older plants, sometimes stumps nearly full size may be seen that have shed all their leaves (See Fig. 8, p. 269, illustration at left.) This deciduous nature of the leaves is very characteristic of the Fusarium wilt. No broken lesions are to be noticed on the stems and roots unless decay (bacterial and fungus complication) follows, which does occasionally take place.

In the case of bacterial association the plant may show a very quick wilt. Sometimes, when the disease has gained entrance to the vessels in one part of the cabbage, the yellowing symptoms may show only on one side. Under such circumstances, a sunken but unbroken lesion may be observed indicating the course of the fungus (See Fig. 6, page 267). Cross sections of infected stems and roots, when not complicated with bacterial activity, show a light yellowing or browning of the vessels. The presence of bacteria in the vessels changes this coloring to a dark brown or jet black. This coloring of the vessels in advanced cases extends clear up into the petioles of the leaves. By cultures, it is not difficult to demonstrate that the fungus actually penetrates the petioles, thus definitely proving that fallen leaves are a means of disseminating the disease. Maturing plants which have become sufficiently infected to show external symptoms, are not accepted as marketable by buyers.

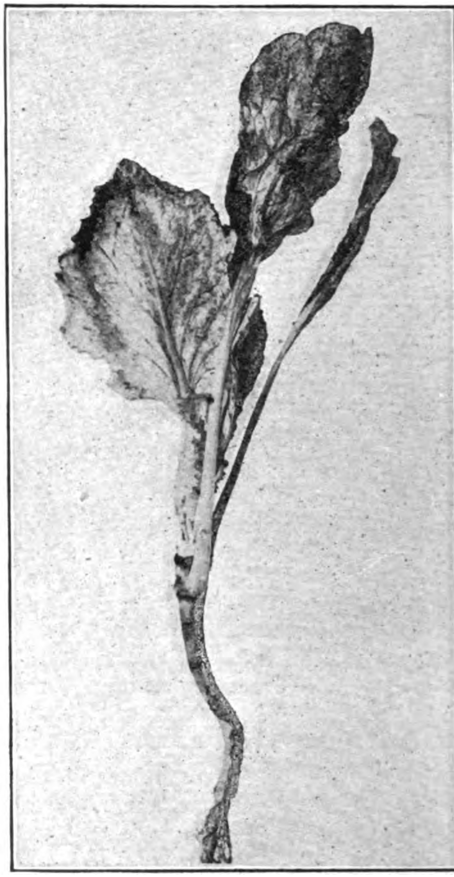

Fig. 5. Cabbage seedling showing the yellowing symptoms of Fusarium wilt (See Fig. 10).

INFLUENCE OF SOIL AND WEATHER

This disease is less influenced by soil and weather conditions than are most other fungus troubles. The growers state that the lighter, sandy soils greatly favor the spread and activity of "yellows". There is some evidence which supports these statements. A light sandy field east of Clyde, which on August 4th showed about 1 percent infected with the Fusarium wilt, on September 13th showed between 15 and 25 percent wilted. A nearby field consisting of low, black soil, which on the first date showed 15 percent sick with Fusarium wilt, had increased but little by the latter date. The Fusarium wilt of flax, a similar disease, in the northwestern states makes much more rapid progress in the lighter soils of central North Dakota, than in the heavy, black soils of the Red River Valley.

n abundance of humus favors its spread and persistance in il. However, in this regard it is evident that soils which are way suitable for cabbage will contain sufficient organic rial to supply the needs of this organism. Excessive rains are ys a means of distributing soil troubles. In this regard the trium wilt of cabbage is no exception. Droughty conditions surface distribution, while on the other hand, the aggressive ire of the disease is always aggravated by dry weather.

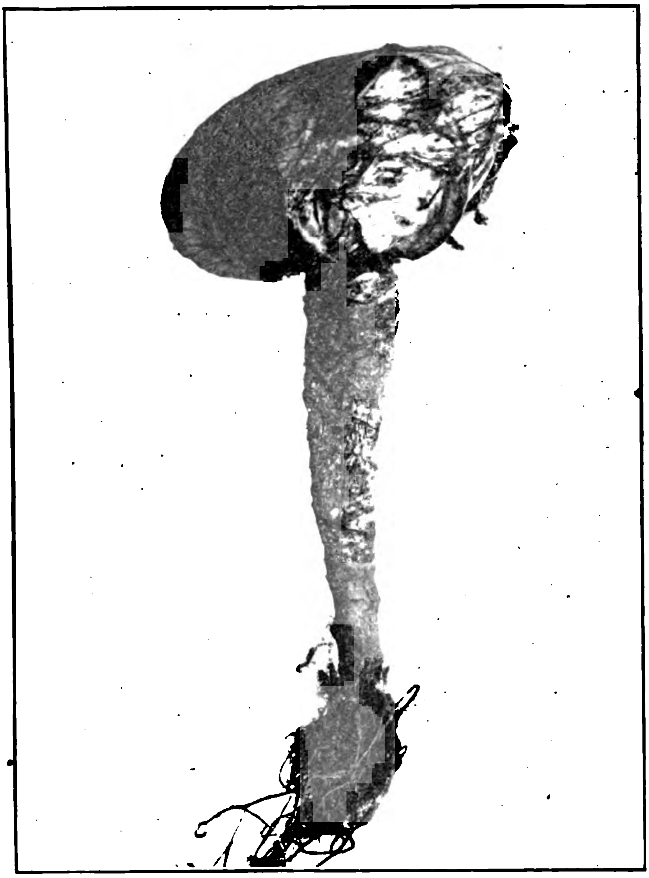

Fig. 6. A partially matured plant that has succumbed to the Fusarium wilt. In the upper shaded part of the stem is a sunken area showing the course of the disease.

TREATMENT

Parasitic diseases of field crops which are also persistent soil organisms seldom admit of definite treatment economically. In the case of club-root of cabbage the causal organism gradually succumbs to heavy applications of lime. Potato scab, on the other hand, is increased by lime. In the case of cabbage wilt (Fusarium) no specific treatment is known.

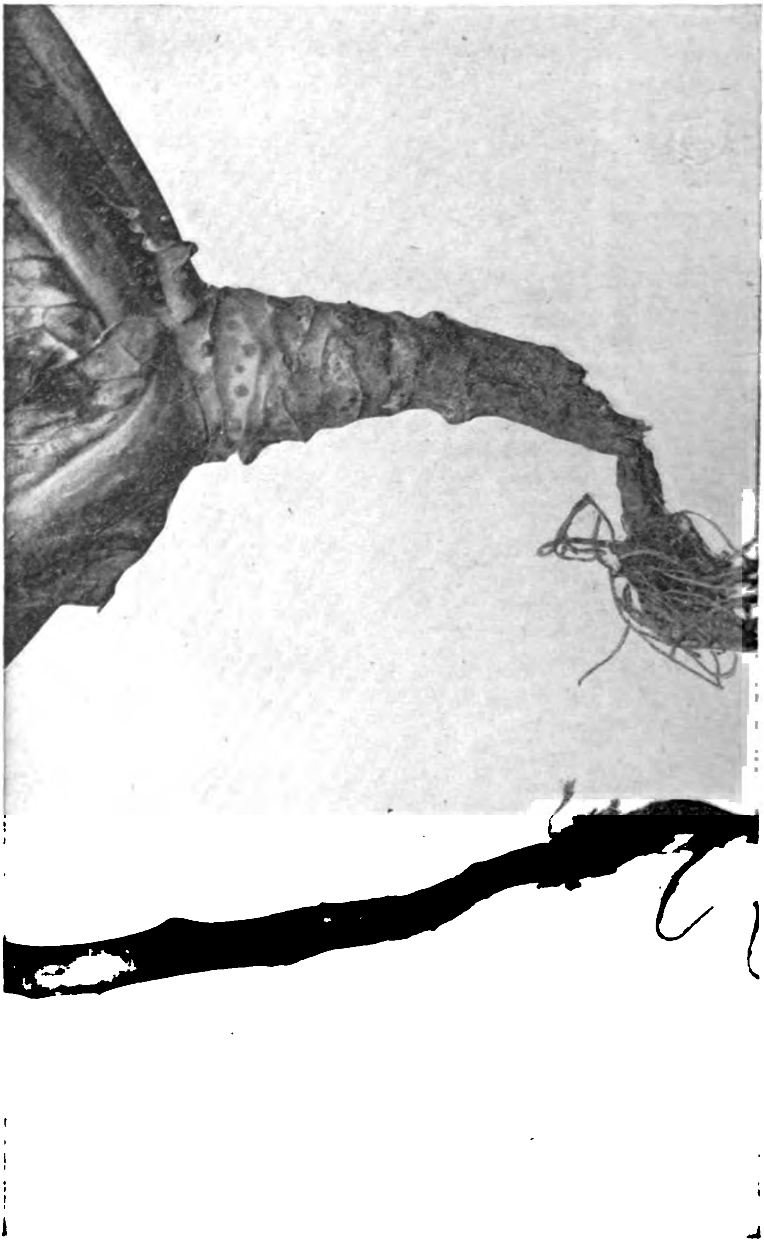

Fig. 7. Illustration showing the external characteristics of Phoma wilt (black leg). The seedling at the left shows the lesions as they appear on the stem, often previous to transplanting. In these sick spots are found small black bodies, the fruit (pycnidia) of the fungus which causes the disease. At the right is shown a partially matured plant that has just collapsed from the disease. Note how the stem and main root have been practically rotted off. In this case, no adventitious roots have been sent out. (See Fig. 18 for adventitious roots). Compare this illustration with Figs. 5 and 6 for contrast of Phoma (black leg) and Fusarium wilts (yellows).

MEASURES LOOKING TOWARD CONTROL

Though no specific treatment has, as yet, been worked out, there are many preventive or restrictive measures which may be practiced. In addition to those recommended (pp, 260, 261) the following should be carried out: Diseased plants should be gathered and burned or dumped in places from which no further spreading is assured. Small diseased areas should be worked entirely separate from the field as a whole, in this way preventing distribution by implements and animals.

Fig. 8. Comparing at the left, stem of plant defoliated by the Fusarium disease, with plant at right affected with the Phoma wilt. Note, that the plant at the left shows no rot on the stem, while the plant at the right has broken at the stem due to rot from the Phoma disease. Both plants are the same age, about one-third grown.

It is important to become familiar with the disease in all its symptoms, to be able to detect the first signs of the disease in the seed bed; and to absolutely avoid using plants from beds in which even the slightest trace of the disease appears. The practice of

putting out two or three seed beds on non-infested areas is to be recommended. This will give an opportunity to select the least infected and most vigorous plants. We must keep in mind that the seed bed is a minor expense. To be limited to weak and infected plants is a heavy handicap.

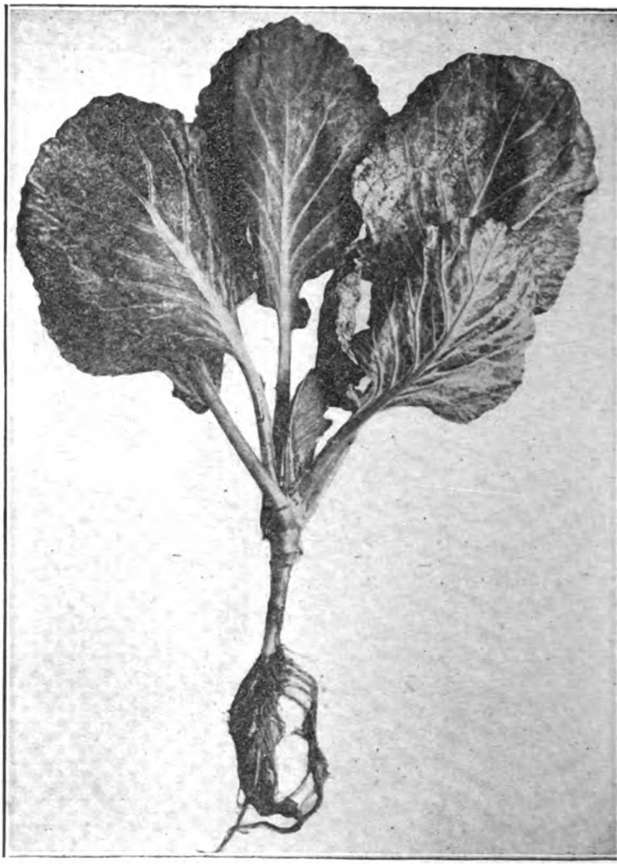

Fig. 9. A healthy cabbage seedling. Compare with the plant shown in Fig. 10, which was taken from the same bed, and was of the same age.

In case a few scattered infected plants are discovered in the field, these should be carefully removed and immediately burned or otherwise destroyed. The disease spots should be marked and all to and fro cultivation over these infested areas should be stopped to prevent distribution by implements. Where the disease makes its appearance, rotation should early be practiced. An accurate record should be kept of the amount of disease which appears in the fields cropped with cabbage, so that when the rotation again brings the land into cabbage an estimate may be made as to whether the disease is on the decline or increase.

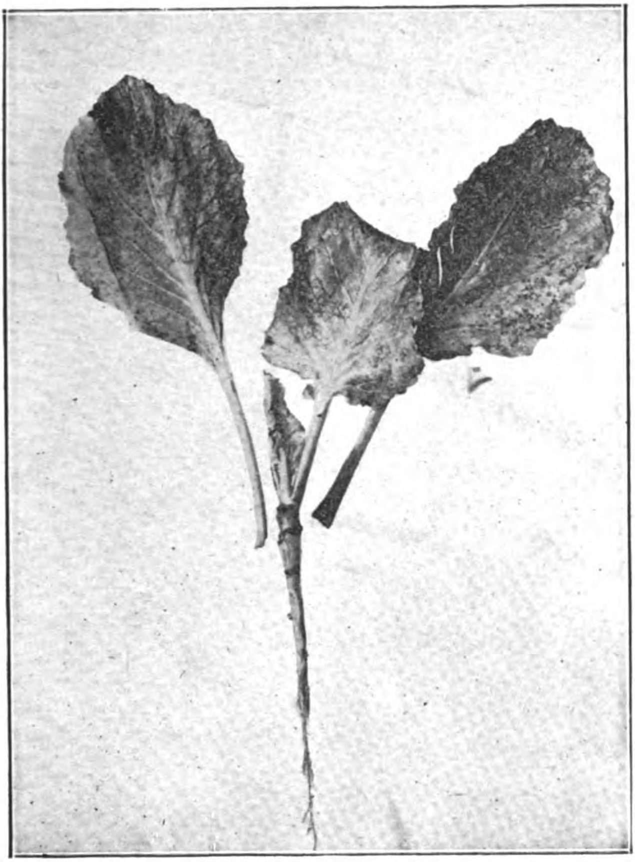

Fig. 10. A cabbage seedling affected with Fusarium wilt, (yellows). The yellowing leaves drop at the slightest touch.

THE POSSIBILITY OF SELECTING RESISTANT STRAINS

Much hope is to be entertained of the possibility of securing resistant strains. This is a work that requires several years for positive results. Sometimes it is desirable even after securing resistant plants to cross-breed these with marketable strains, as it is often the case that resistant strains or varieties are not high yielding or of desirable quality. It would even seem profitable for growers to continue desirable strains, by selecting those of the proper type and yielding capacity. The practice of purchasing

seeds from promiscuous retailers often proves a risky business. One need be no specialist to note that many irregular types, and low quality, poor yielding strains are to be found throughout the cabbage districts. This difficulty can be remedied only by purchasing from reliable seed houses, or by the growing of seed from carefully selected, home grown stock.

Fig. 11. Showing at the left plants slowly dying with the Fusarium wilt. In this field the disease was general, and the loss was excessive. The plants were not quite half-grown. Note the manner of shedding the leaves. *Photographed August 4, 1910, Clyde, Ohio*

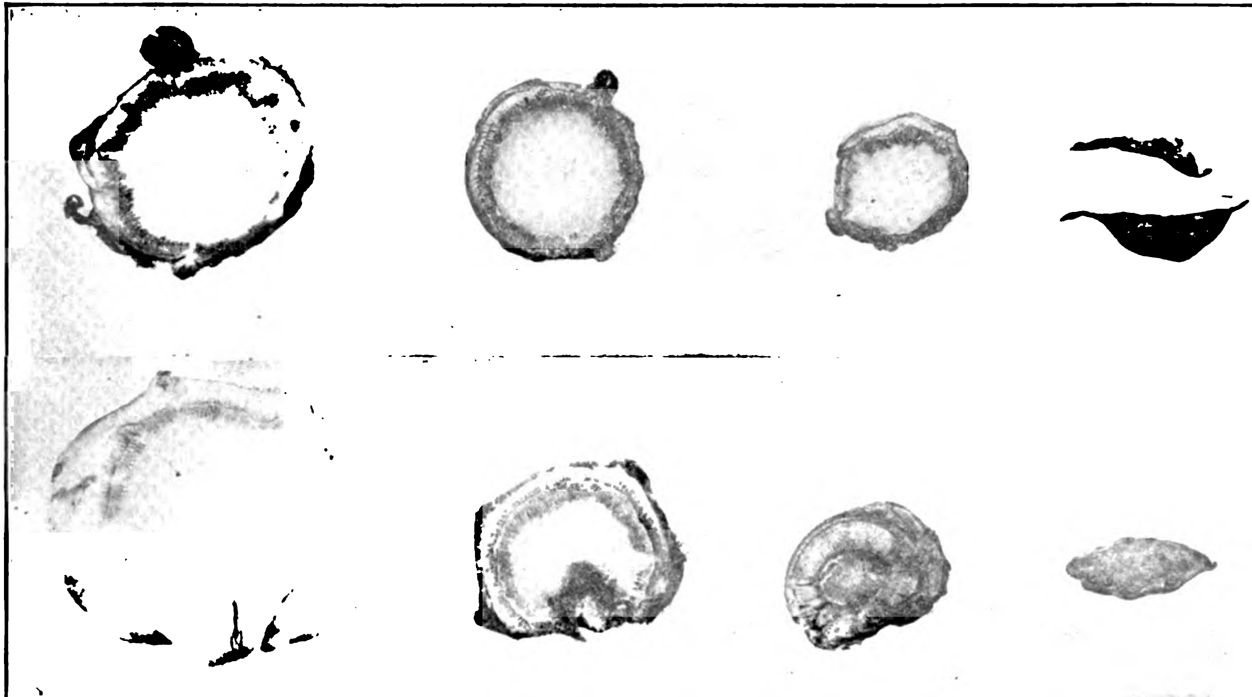

Fig. 12. Showing above, cross sections of a plant infected with the Fusarium disease. The vessels throughout the root and stem have a yellowish to brownish color; this discoloration often extends up into the petioles of the leaves. The fungus may be taken from the petioles by plate cultures, showing that dropping leaves are a means of distributing the disease.

The cross sections below are from a Phoma sick (black leg) plant. The heart shows no discoloration, indicating that the disease works lower down. The chief injury takes place on the stem and root at the level of the ground, or below, where a collar and stem rot is produced.

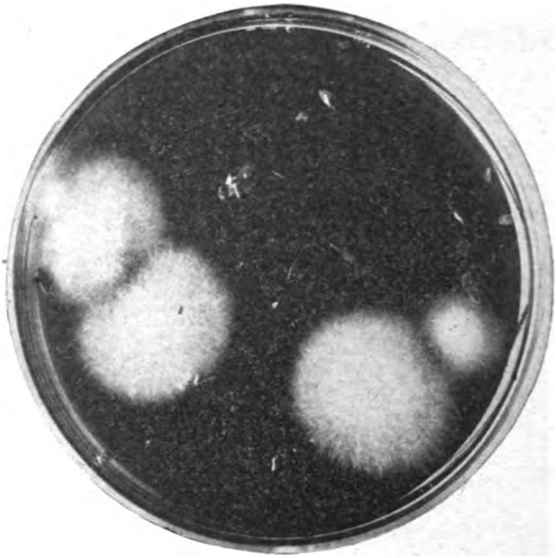

Fig. 13. Showing plate cultures of the Fusarium fungus which causes wilt or "yellows". From a young seedling just showing the preliminary symptoms; in this case a pure culture of the parasitic organism is seen.

Fig. 14. Cultures of the Fusarium wilt fungus from an older infected seedling in which bacterial association had already taken place. As soon as bacterial contamination takes place the seedling rapidly wilts. The bacterial growth in the plate has checked somewhat the growth of the parasitic fungus.

SUMMARY

In summarizing, the following suggestions are emphasized:

1 Learn to know the Fusarium wilt in its earliest symptoms, and to distinguish it from the other cabbage troubles.

2 To assist you, your Experiment Station is always ready. Send in specimens of diseased plants; ask for advice, literature or a personal visit.

3 Treat the seed (see page 259); grow your own plants; put out two or three seed beds a considerable distance from any infested areas; use only the most healthy and vigorous plants.

4 Use no plants from a Fusarium wilt (yellows) infested bed.

5 Use no manures carrying infested cabbage litter.

6 Should light infestation appear in the field, gather all sick plants and burn. The diseased spots should be marked off and cultivated separately. Keep a written record of the infested field, noting the infested spots. In this way you will learn the kind and length of rotation required to work out the disease.

7 Practice rotation upon the appearance of disease. A good rotation pays at all times.

8 If you are interested in continuing cabbage culture, never allow stock to feed promiscuously from infested to non-infested fields.

9 "An ounce of prevention", with this disease, "is worth a *ton* of cure."

10 Early learn to know the persistent nature of this disease as a soil trouble, and likewise, the improbability of working out a curative treatment.

BLACK-LEG OR FOOT ROT OF CABBAGE

Phoma oleracea Sacc.

This disease may have reached us from European countries where it has been known for a number of years. France, especially, has lost heavily from what appears to be the same trouble.[5] In the Province of South Australia, vicinity of Auburn, growers of cabbage and cauliflower, especially the latter, have recently met with considerable losses from this disease.[6] Germany, likewise, has been subject to the trouble for sometime. More recently the disease has made its appearance in North Holland, where it has been made the subject of extensive experiments.

In the state of Ohio the disease has been known for only a short time, the attention of the Department being called to the trouble by the writer on a visit to Fremont, Sandusky county, during the spring of 1910. The seed beds showed considerable infestation previous to the time of transplanting (See Figs. 15, 16 and 17, pp. 279, and 280).

During the summer, through letter and visitation, the writer has found that the disease has made its appearance throughout Ohio in a number of places. Specimens have been received from Fremont and Clyde, Sandusky county; Greenspring, Seneca county; and Englewood, Montgomery county, and correspondents further report the disease from Hamilton, Medina, Washington, and Ashland counties.

THE DISEASE IN EUROPE AND AUSTRALIA

The literature upon the disease is very limited. Prillieux and Delacroix[7] give a careful description of the disease as it appears in western France in the Province of Vendeé on the cabbage grown for fodder. They designate the trouble, "Foot-Rot of Cabbage" (Pourriture des pieds de Chou) and state that the disease is of considerable importance, attacking and rotting the stems, causing much loss. The fungus assigned as the source of the trouble is *Phoma Brassicae* Thüem. In Australia, the disease has been carefully studied by D. McAlpine[6], who calls the

[5]Dept. of Agr., Victoria, Fungus Diseases of Cabbage and Cauliflower in Victoria, and their Treatment, by D. McAlpine, January 1901.

[6]Prillieux and Delacroix, Bul. de Societe Mycol. 6: p. 114, 1890, also Maladies des Plantes Agricoles 2: 295-297, 1897.

[7]Prillieux, Maladies des Plantes Agricoles, 2: 295-297 1897.

trouble "Black-leg" or "Foot-rot" and states that, in 1901, cauliflower in some instances suffered losses of 25 percent or more. He says:

"This cauliflower disease was also met with at Brighton, and Mr. Cronin, inspector under the Vegetation Disease Act, called attention to the serious nature of it in June of this year, stating that fully 90 percent of the plants were affected in some instances, and estimating the loss in the Brighton district at £5,000 ($25,000), one grower alone sustaining a loss of £200 ($1,000). I visited this district in August, and found the disease not only on cauliflowers, but also on cabbages."

In speaking of the severity of this disease, after mentioning four other diseases, viz., Club-Root, White-Rust, Ring-spot of Leaf, and Putrefactive Mildew, he says:

"The 'Black-leg' is perhaps the most serious trouble with which the grower has to contend, and the neglect of it for a number of years past, combined with the encouragement given to its spread by ignorantly plowing in the diseased portions, has given it a strong foot-hold in the (Brighton) district"

He notes that the disease causes collar-rot of the roots and stems of cabbage and cauliflower, and that it is not uncommon to find it upon the leaves of these plants, and also upon those of turnip and rape. He states:

"In every instance the superficial tissue of the diseased roots and stems showed numerous black punctiform bodies, which usually did not extend above ground."

He assigns the fungus *Phoma Brassicae* Thüem as the causal agent.

In the Province of North Holland, vicinity of Langendijk, the disease is known in two forms: one, a field trouble, is given the name "Fallsucht" that is, drop disease or falling sickness, (See Cit. 2 and 3 p. 260) signifying the characteristic termination of the disease (See Fig. 4 p. 265, cabbage at right); and the other a storage trouble called "Krebsstrunke" (cancerous stems), in which, during February and March, yellowish-gray, cancerous spots appear in the axis of the leaf and extend onto the leaves. (See Fig. 19, p. 283, showing sick spot on growing plants). These lesions increase till the leaves rot off. In reviewing the trouble in the Province of North Holland, Professor Bos (see Cit. 2, p. 260) says:

"The neighborhood of Langendijk is really the center of cabbage culture in Holland. Here, year after year, so much cabbage is grown that a proper rotation is impossible; upon many of the fields cabbage has been continued for twenty years. Thus one can understand that many diseases must come in; one really wonders that these diseases do not take the upper hand and make cabbage culture an impossibility."

In speaking of the trouble he states that the chief symptom of this disease consists in the dying of the main root, close to the surface of the earth, and notes that the disease in the field may be distinguished by the bluish-red color of the leaves. He attributes the disease to the fungus *Phoma oleracea* Sacc.

SYMPTOMS

The work of the disease is early noticeable in the infected seed beds, being often conspicuous one or two weeks before transplanting. The preliminary symptom is that of white, sunken, elongated oval areas on the stem, usually below the point of leaf attachment (See Figs. 15, 16 and 17, pp. 280, and 281). There appear early in these lesions, small black bodies equally distributed over the affected areas; these black specks are the fruiting bodies (pycnidia) of the fungus. Within each pycnidium are myriads of hyaline spores through which the fungus is propagated (See Fig. 22, p. 288). In these early stages of the disease the fungus may be plated out in almost pure culture by a surface sterilizing of the infected material. This is not true later, however, as these infested areas soon become confluent, the tissues die and break open, following which, bacterial and fungus contaminations set in. (See Figs. 15, 16, 17 and 18, pp. 279, 280 and 281).

In the preliminary attack, the disease causes no foliage change through which the trouble may be distinguished, unless lesions are formed directly on the leaves, which seldom occurs in the seed bed (See Fig. 20, p. 284). Seedlings about to collapse with the disease take on a bluish red color of the foliage. The growers, as a rule, discard all plants observed to have stem or leaf injury from this or other cause.

The dissemination of the disease is not so much a matter of overlooking the planting of infected seedlings, though undoubtedly much of this takes place, as it is of general distribution of spores through the handling of occasional sick plantlets.

Plants affected with this trouble die in all stages of their growth; few, however, succumb previous to the transplanting, and only those more or less badly affected at the time of setting out die within the following three weeks. The greatest loss takes place at the time when the plants are one-half to two-thirds grown, at which time the symptoms are very characteristic. The foliage of the affected plants takes on at the margins a mottled, metallic, bluish-red color. The lower, outer leaves show evidence of wilt. Total collapse may take place in 24 to 48 hours (See Fig. 4, p. 265, plant at right). Examination of the stems and roots of partially matured, infected plants always reveals large, sunken lesions extending one-half to two-thirds the distance through the stem or sometimes showing a sunken collar-rot, so far destroying the stem as to allow the top to break off easily, and as Mr. Guy Wickert of Fremont says, "Uproot and blow away with the wind." (See Fig. 7, p. 268 and Fig. 18, p. 282).

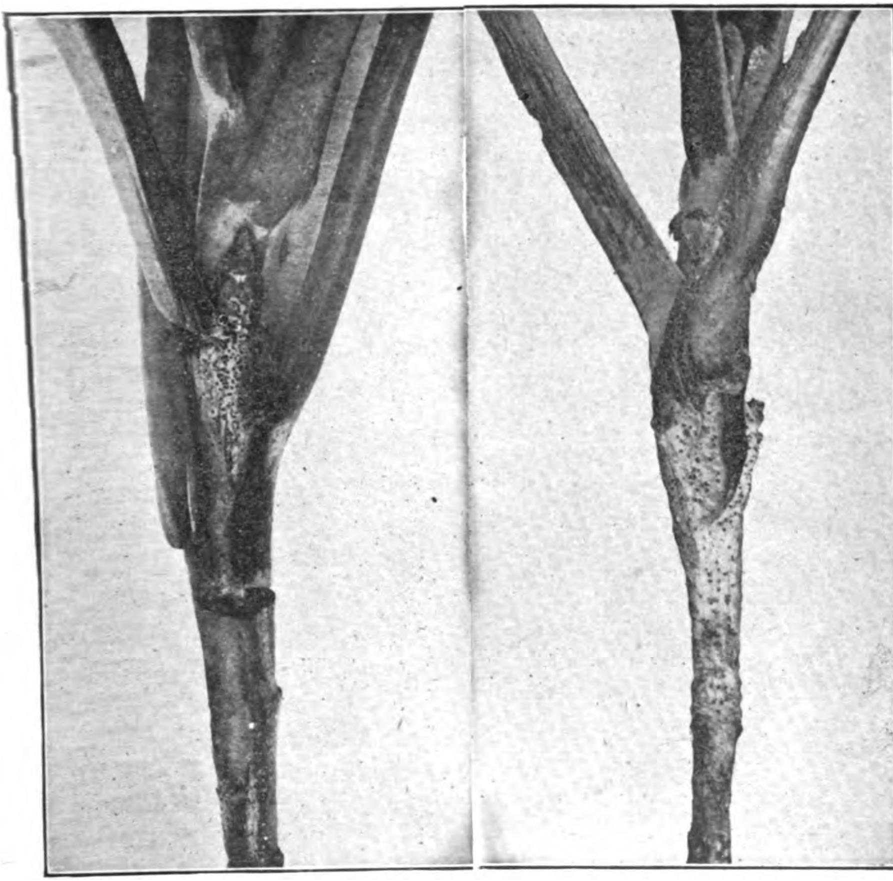

Fig. 15 Fig. 16

Seedlings of cabbage magnified by 1.8 and 3 diameters respectively showing the early stages of "Black-Leg" or Phoma wilt. Plants taken from the seed bed at transplanting time. Observe in the plants the infected area containing many fruiting bodies (black dots, called pycnidia) of the fungus *Phoma oleracea* Sacc. which is the cause of the disease.

If rains are favorable, the infested plants may set root again from above the place of injury. (See Fig. 18, p. 282). These adventitious roots are seldom sufficient to mature a marketable product.

Fig. 17. Plant taken from the seed bed at transplanting time, showing infection just above the rootlets, in which a collar-rot is taking place.

CAUSE OF THE DISEASE

The disease has been associated in the past by some with insect work, hence, much error has been connected with its diagnosis. It hardly seems probable that it has not been noted in the United States heretofore by plant pathologists. F. L. Washburn[8], State Entomologist for Minnesota, in his report to the Governor for 1906, states, in writing upon club-root of cabbage: "Many market gardeners confound the work of the maggot with diseases which affect the root and have no connection whatever with maggot. This is noticeably true of a form of rot which sometimes affects the roots, causing wilting and death of the plant." It appears very probable that the above writer is referring to what is here called *Phoma* wilt or "black-leg," as it is the only fungus rot of the cabbage root.

In Australia, McAlpine makes no mention of insects being associated in causing the trouble. Prillieux, in his work on plant diseases, in no way refers to the disease being favored by insect activity. On the other hand, Bos and Quanjer in Holland, following their experimental work, claim that the disease is quite closely associated with the activity of the cabbage maggot. Indeed, Quanjer goes so far as to state (see Cit. 3, p. 266,):

[8]Washburn, F. L., Report of State Entomologist, Minnesota, 1906.

"The control of the drop disease depends chiefly upon the proper control of the cabbage fly. Since nature, in an epidemic of these parasites, has not as yet come to our assistance, it is left to us to overcome this difficulty; accordingly, we will be directed towards preventive means. One should clean the plantlets, before placing in the field, by washing away the adhering earth and by cautiously rubbing the stem and the leaf axes in order, if possible, to destroy the clinging eggs of Anthomyia (the cabbage fly) and Baris (the cabbage curculio*). After planting, the stems of the plantlets should be protected from the cabbage fly. However, the paper collar, which I have mentioned above, for this purpose is quite inadequate, because through the thickening growth it is subsequently brought into an improper position. More practical is it to throw a handful of slacked lime about the stem. In a limited way, this method has been proven; however, it will be tried extensively this year in the experiment fields of Langendijker."

Bos states (see Cit. 2, p. 260) that, in the order of their susceptibility to the disease, the red cabbage is first, then Savoy and Danish head cabbage, and last, though in a much less degree, cauliflower.

McAlpine (See Cit. 5 p. 276) notes that the disease is most severe in cauliflower.

Washburn,[9] in working with the cabbage maggot states "Holland cabbage appears to be exempt from attack, no cabbage maggots being found in this variety. Red cabbage, on the contrary, is not immune, since it suffers from the attacks of the maggot."

In speaking of the maggot work on cauliflower the same author says: "The cauliflower was a complete failure, there being only three heads out of the fifty plants when counted July 26th."

I quote from the different writers above, to show that much variation takes place. For example, in Australia cauliflower is most subject to the disease while in Holland it is least. In Minnesota, Holland Cabbage is exempt from the work of the maggot, while in Holland it is more subject to the Black-leg than the cauliflower. As previously noted (p. 280) Washburn states there is a root rot and wilt of the cabbage which has no connection whatever with the maggot.

The observations made by the writer in the seed beds and fields, together with experiments upon seedlings of the varieties "All Season" and "Market Garden," convince him that the importance of insect association, as noted by Bos and Quanjer in Holland, does not apparently hold true for the disease in our districts. In fact, the disease was produced in abundance in seedlings by placing washings from diseased material with the seed at the time of planting. Many of the plantlets died before the third leaf was formed (See Fig. 20, p. 284). No association whatever of maggots was found with this early seedling infection.

[9]Washburn, F. L., Bul. Minn. Exp. Sta., 112: 1908

*The insertions in the parentheses are the writer's. It appears that *Baris rapae* and *Ceutorhynchus rapae* Gyll. are synonyms. (10) See Bul. Ohio Agr. Exp. Sta., 77, Feb. 1897, by F. M. Webster.

Fig. 18. "Black-Leg" or Phoma wilt in the advanced stages. Showing the stem completely rotted off and the foliage collapsed (wilted). The plants have attempted to re-establish themselves by throwing out adventitious roots above the point of injury.

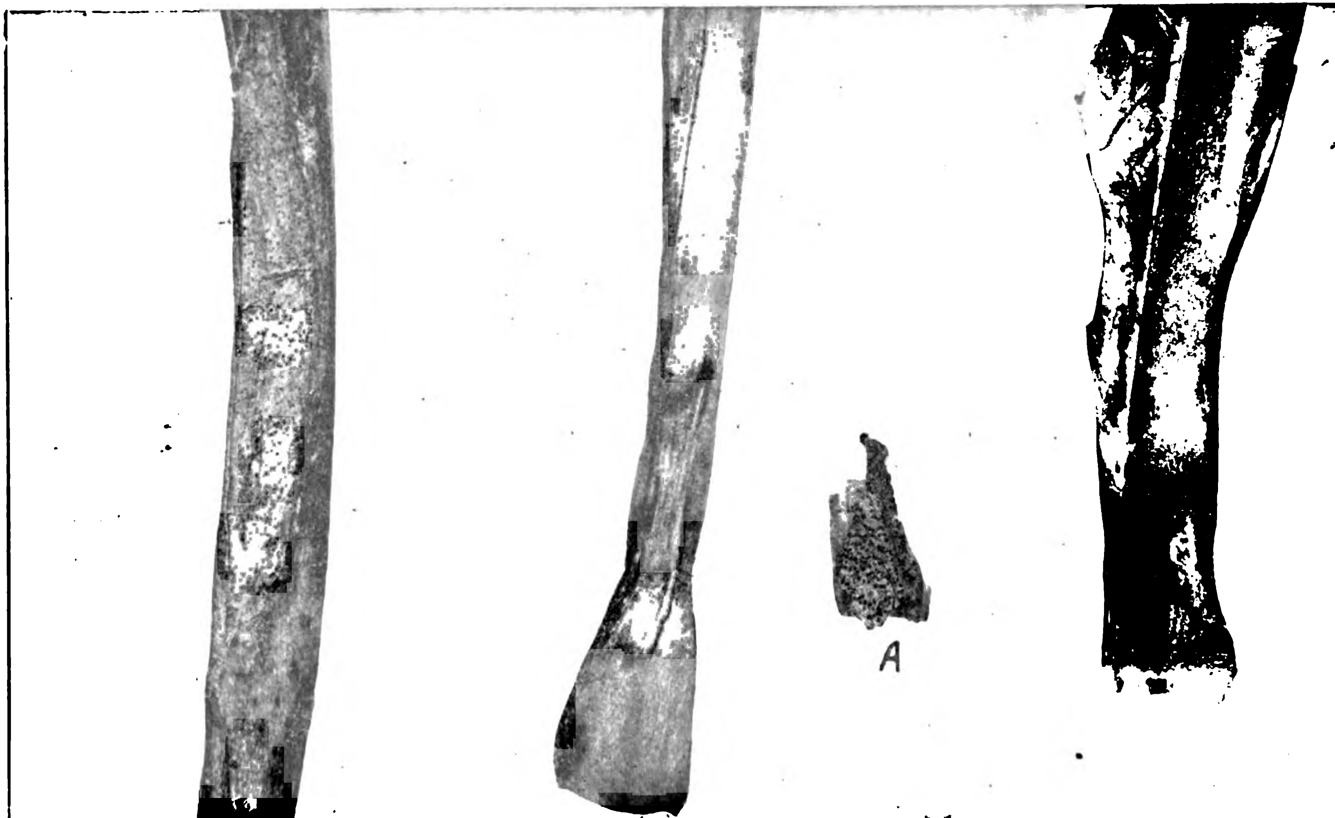

Fig. 19. Showing the "Black-Leg" fungus *Phoma oleracea* producing cancerous spots on the petioles and blades of cabbage leaves. Note at the left the fruiting bodies of the fungus scattered evenly throughout the lesions. The small piece marked A, which is also covered with fruiting bodies was taken from a

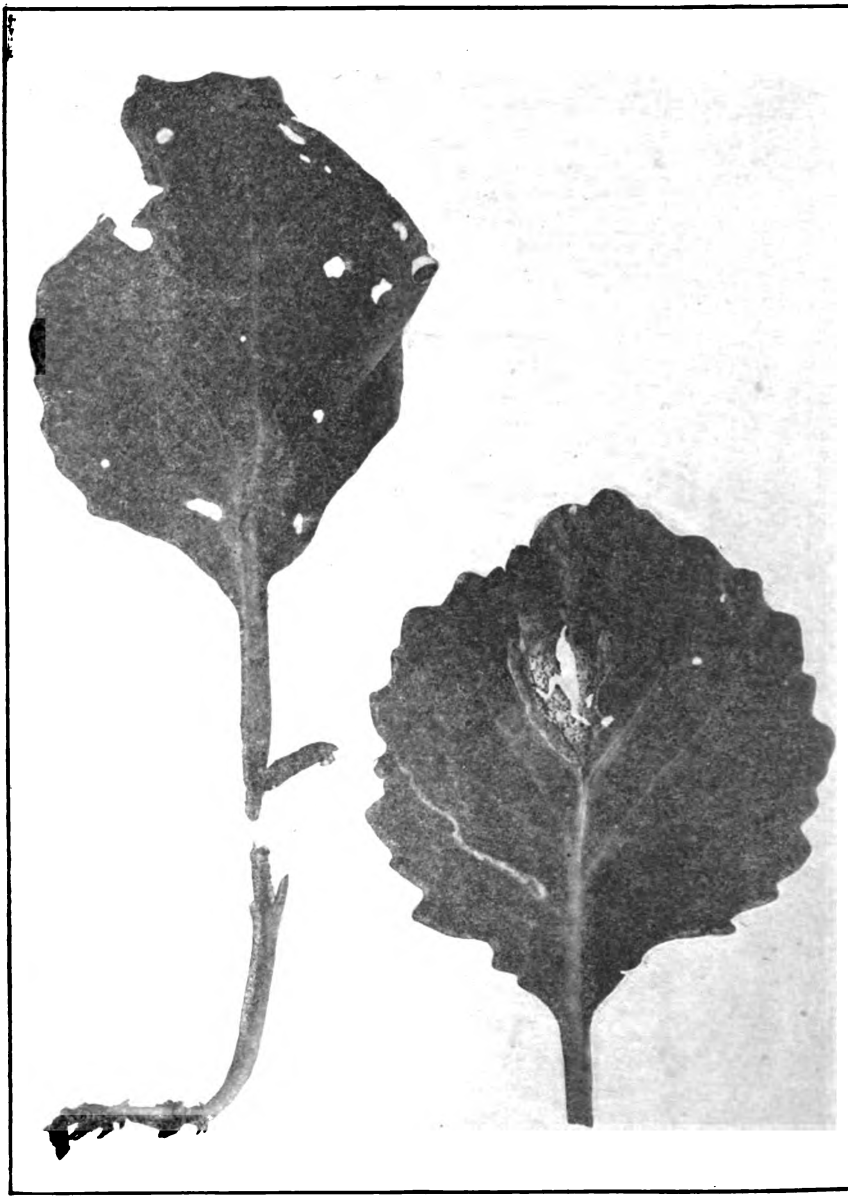

Fig. 20. Showing seedlings of "All Season" the variety of cabbage infected on the leaves with the fungus (*Phoma oleracea*) which causes "black-leg" or "foot-rot." In the seedling at the left the disease has entirely rotted off the stem above the seed leaves.

Direct experiments with pure artificial cultures of *Phoma oleracea*, inoculated into the stems of half matured cabbage plants just below the surface of the ground by means of a slight cut into the cambium with sterile scalpel, gave 100 percent of infection. One of the plants showed a total collapse from a collar or cambium rot. Several others would have succumbed in a short time as the cambium was nearly destroyed.

The incisions made in the check plants healed up nicely with no evidence of rot.

I have seen maggot borings at four or five places on a single cabbage stem and root without any evidence whatever of rot following. Wherever *Phoma* "foot-rot" is found associated with the maggot work, it simply means that the insect has made it easier for the fungus to get a foothold.

In examining a large number of *Phoma* wilted plants in the Clyde district, by cutting longitudinal sections of the injured roots, only three showed insect work, in which case the larvae associated appeared to be those of the small flies which are common in rotting vegetables. In one case two white maggots about 7-20 of an inch in length, were present; these upon pupating, turned brown and were between 3-20 and 7-40 of an inch in length. These measures correspond closely to those of the cabbage maggot.

The direct cause of the disease is a fungus, scientifically known as *Phoma oleracea* Sacc. The arrangement of the fruiting bodies (pycnidia), their size, ¼ to ⅓ millimeter in diameter, together with the spore measurements (4.5 to 5 m. m. m. by 1.7 m. m. m. to 2 m. m. m.), and other characteristics, all indicate the organism to be the above named fungus.*

There is little doubt that insects, viz., the cabbage maggot, the cabbage curculio and wireworms may be and quite generally are instrumental to some degree in distributing and facilitating the fungus in its work on the cabbage. On the other hand, the evidence is sufficient to show that the fungus is a direct pathogen on seedlings and susceptible plants. (See Figs. 15, 16, 17, 19, 20). Under

*Some discussion should be given here to the assigning of *Phoma Brassicae* Thüem. as the causal organism of this disease by Prillieux in France and McAlpine in Australia. According to Bos (see Cit. 2 p. 260) there is reason to believe that the organism assigned by Prillieux viz., *Ph. Brassicae* Thüem. is identical with *Ph. oleracea* Sacc. In the description of the two species, *Phoma Brassicae* and *Phoma oleracea*, (See Saccardo, Sylloge Fungorum, III, 119 and 135), as far as measurements are concerned, there is hardly difference sufficient for any specific distinction. On the other hand, the arrangement and number of pycnidia would seem to be a basis for such distinction, to wit:

"*Phoma Brassicae* Thüem. Peritheciis majusculis, dense aggregatis, saepe confluentibus * * superficialis; sporilis * * 3-4=1.5-2. mmm"

"*Phoma oleracea* Sacc * * Peritheciis sparsis, globosso-depressis, papillulatis, ¼-⅓ mill. diam., * * sporilis 5-6=2 mmm., 2 guttulatis, hyalinis."

Prillieux's illustration of the pycnidium (See Cit. 7 p. 276) shows the pycnidia to be arranged singly and submerged, similar to *Phoma oleracea*.

McAlpine, on the other hand, in his Plate VII (Cit. 5 p. 276) shows photo-micrographs in which the pycnidia are superficial and densely aggregated. These distinctions would seem to justify McAlpine in designating the organism as *Phoma Brassicae*.

warm, damp storage conditions the fungus spreads rapidly. In shipping by express a number of infected plants from Clyde, Ohio, in which the shipment was five days in transit, the disease spread rapidly over the plants, fruiting abundantly on the partially wilted leaves.

LOSSES FROM THE DISEASE

This disease is much more irregular in its work than is the Fusarium wilt. The latter gradually increases, but most surely comes to stay. On the other hand, the Phoma wilt may be found only upon 5 percent of the plantlets in the seed bed, and yet become so thoroughly disseminated during transplanting as to cause almost a total loss. Several fields this season (1910) have shown losses varying from 20 to 70 percent, the disease coming directly from the seed bed. In 1909 almost total losses were caused in several of the fields which had previously never grown cabbage. Evidence has been obtained in which heavy loss came about from previous field infection. At Fremont there were sick spots of one-fourth acre or more in size in the fields which would indicate previous soil infection. Infection and dissemination at transplanting time is indicated by certain rows being badly infected, or by a quite uniform percentage of infected plants throughout the field, as contrasted with sick areas where previous soil infestation occurs.

INFLUENCE OF SOIL AND WEATHER

Growers in the Clyde district make the statement that the "Wilt" (black-leg or Phoma wilt) makes its greatest progress on the black soils. The observations made this season by the writer partially confirm these statements. The disease, however, is in no way strictly confined to the heavier soils. This season the loss in a field on about the lightest soil in the vicinity of Clyde was over 5 percent from this disease on an area which had not previously grown cabbage.

Moisture appears to be more favorable than the soil texture as a factor influencing the spread of the disease. In seasons which are moist throughout, the distribution and activity of the fungus is greatly accelerated.

TREATMENT

This disease is a soil trouble which carries over from season to season through infected stems and leaves. As a rule, persistent soil parasites do not submit readily to treatment. There are, however, exceptions to this statement, and the writer is inclined to believe that in this organism we have such an exception. The kinds of soil organisms which do submit to treatment are usually those which cause a stem rot at level with, or just below the surface

of the ground. Rolfs[12], of Florida, has found that by spraying the ground around the stems of tomatoes with ammoniacal copper carbonate, he could successfully control the sclerotium blight. In Cuba[13] the use of Bordeaux mixture, when sprinkled thoroughly on the tobacco seed beds, controlled bed rot (a disease caused by Rhizoctonia) "with complete success."

McAlpine (see Cit. 5, page 276) has found that a strong solution of bluestone is very effectual in controlling a serious soil disease of tobacco, when the solution is applied the same day the seed is planted. He recommends for this disease (Phoma wilt) that the seed beds should be treated, preparatory to sowing, with a fungicide such as sulphate of copper.

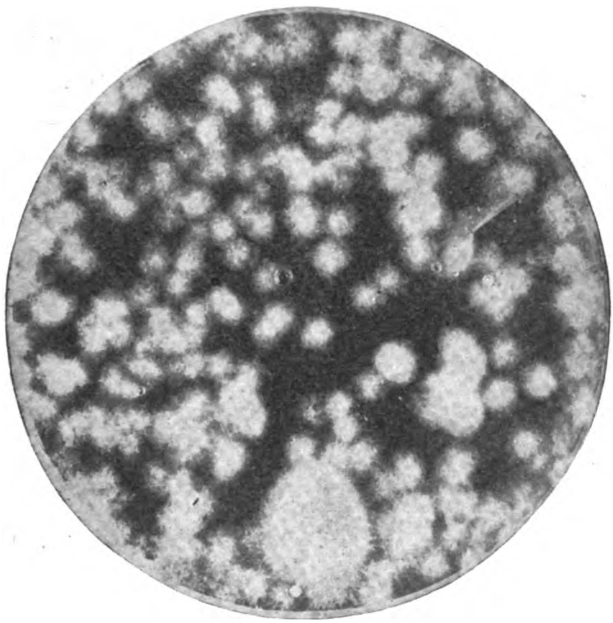

Fig. 21. Showing plate culture of *Phoma oleracea* Sacc. on an artificial medium The white fungus growth came from small spores taken directly from a pycnidium (spore sac) see B. Fig. 22.

The writer has experimented upon the use of both Bordeaux mixture and a straight solution of copper sulphate (bluestone) for this disease upon cabbage seed beds at time of planting and upon seedlings three weeks old. The formulas used were, for the Bordeaux, 4 lbs. copper sulphate, 4 lbs. lime, to 50 gallons of water—and in the straight copper sulphate solution, 4 lbs. of copper sulphate to 50 gallons of water.

12P. H. Rolfs, Tomato Diseases, Bul. Fla. Agr. Exp. Sta. 91: 1907.

13Estacion Central Agronomica, Cuba, Cir. No. 28: 1907 and Circ. No. 30: 1908 Eng. Ed. "Soil Sterlizing, Bordeaux Mixture and Poisons for Tobacco Seedbeds" by William Titus Horne.

The solutions were used in two different amounts. The Bordeaux at the rate of two gallons per 10 square feet and one gallon per 10 square feet. The copper sulphate solution was used at the rate of one gallon per 10 square feet and one-half gallon per 10 square feet.

The Bordeaux mixture in no way retarded the growth of the seed or injured the seedlings; on the other hand, the copper sulphate solution, though apparently in no way retarding the germination, considerably scorched the leaves of the seedlings.

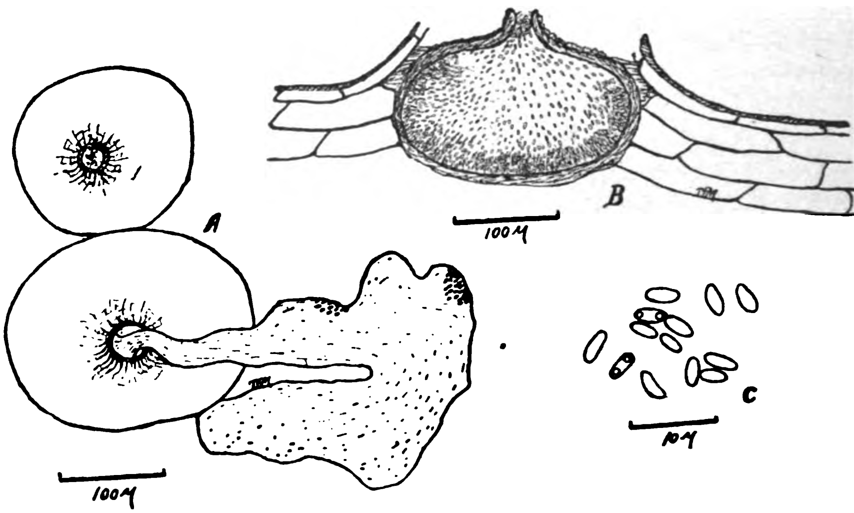

Fig. 22. A, showing fruiting bodies (pycnidia) with spores streaming out in a mass. Slight pressure brings out myriads of spores from each spore sac, every spore being capable of reproducing the fungus of the disease. (Highly magnified)

The writer would recommend treating the seed beds, immediately after planting, with a Bordeaux mixture (4-4-50 formula) at the rate of one gallon per 10 square feet. Use a sprinkling pot, or a foot spray pump. The bed should again be sprayed, using a spray pump, two weeks before transplanting, and again just before transplanting. These treatments will keep the disease down in the seed bed, and prevent distribution of the disease during transplanting.

Quanjer (see quotation p. 281), in Holland, states that a handful of slaked lime thrown about the stem after transplanting has worked satisfactorily in keeping the disease in check. Though this has not been tried by this Station, it would seem worthy of trial by cabbage growers and it is recommended to such by the writer.

OTHER MEASURES LOOKING TOWARD CONTROL

Too much emphasis cannot be placed upon prevention. We must remember that in new areas being devoted to cabbage growing none of these troubles, as a rule, is present. Their introduction and wholesale distribution are due to a combination of our indifference, our ignorance of their manner of coming, and to our failure in using precautionary measures for prevention. Since the cabbage maggot and other insects are in a measure instrumental in furthering this disease, much effort should be centered on keeping down these pests. No better means is afforded than the destruction of the material on or in which they breed. This is almost as true with regard to certain fungus diseases. Destruction prevents distribution. Washburn (see Cit. 9, p. 280) in Minnesota, has had some success in controlling the maggot with white hellebore. Keep in touch with your Entomologist at this Station for methods of destroying these insect pests. Washburn (same Cit.) finds that the Holland cabbage is exempt from the maggot attack (see p. 281.) Hence, grow varieties free from the work of this pest.

Too much importance cannot be placed on selecting areas for seed beds that are not already infested. Great care should be exercised in seeing that the disease is not carried to the seed bed by the shoes having previously crossed infested areas.

SUMMARY

1 The "Black-Leg" or Phoma Wilt is a severe cabbage disease which is causing much loss in certain districts of Ohio, page 286.

2 The disease is active also in Germany, France, Holland, and Australia, causing in certain districts much loss.

3 In non-infested districts it would seem possible to prevent the disease from getting a foothold by practicing seed treatment, page 259, and bed treatment, page 287-289.

4 In infested districts it is well to avoid the disease by placing the seed beds on non-infested soils. Infested fields should be placed under proper rotation.

5 Likewise, in older districts seed and bed treatment should be practiced. It would also seem advisable to try the lime treatment (see page 288.)

6 Whether the district is new or old it is recommended to change the seed bed to a new location every year. By so doing, both insect and fungus pests will be much avoided. Put out two or three seed beds some distance from each other. Use only those plants which are the most vigorous and healthy.

7 Use no plants from beds sick with the Phoma wilt or the Fusarium wilt ("yellows"). The appearance of sick plants in the bed most likely means that the whole bed has become infested.

8 Plow up the seed beds as soon as the transplanting is done. Old seed beds are fine breeding places for insect and fungus troubles.

9 In no wise allow stock to pasture promiscuously from infested to non-infested fields.

10 Prevent, if possible, infected cabbage litter from reaching the manure.

11 The chief means of distributing the disease is by handling at the time of transplanting, when the spores from the few infected plants are smeared upon the non-infected. Spray the seed bed thoroughly with Bordeaux mixture just before transplanting.

12 Much irregularity is found in the type and quality of cabbage in the Clyde and other cabbage districts. This comes about by purchasing a miscellaneous seed supply. Buy from reliable seed growers only.

13 To assist in determining the different diseases, make use of your Experiment Station.

14 Discuss plant diseases at your institutes.

NOTE: See page 275 for summary concerning Fusarium wilt (yellows).

HOW TO DISTINGUISH FUSARIUM WILT AND PHOMA WILT FROM OTHER CABBAGE TROUBLES

Although these newer diseases, in their symptoms, are quite different and distinct from some of the older troubles, for example, black rot (*Bacterium campestre* (Pam.) Erw. Smith) and maggot injury, yet many errors have been made during the present season by correspondents in the diagnosis of these troubles. Some of the reasons for this come from correspondents being familiar with only a part of the symptoms of each disease, and not being informed regarding each of the different cabbage troubles. Both black rot and Fusarium wilt cause yellowing and browning of the cabbage leaves; however, when we look into the symptoms further, we find that black rot usually begins its work of yellowing and browning of the leaves at certain points of infection on the margin (see illus., Fig. 23, page 292). These infected areas gradually enlarge until extensive brown lesions are formed; sometimes several such diseased spots are to be observed on a single leaf; often these spots become confluent and the whole leaf dies. There is little tendency of the leaf to break off and drop as in "yellows" (Fusarium wilt). One of the chief symptoms of black rot is the blackening of the leaf veins and veinlets (Fig. 23, p. 292). This is seldom found in "yellows". Accompanying black rot is always the strong odor of decaying cabbage, which is not a part of the Fusarium or Phoma wilt, except in cases where occasional wet rots set in.

Many errors are made in assigning the work of the Phoma wilt to that of the cabbage maggot. The symptoms are quite different in each case, but owing to the maggot assisting in spreading the Phoma wilt, the importance of the latter trouble is often overlooked. The gnawings, furrowings or borings of the maggots are quite conspicuous and characteristic, and the presence of the white larvae in the roots of the older plants (Fig. 24, p. 293) verify the diagnosis. The slower work of the maggots and the characteristic stunting of the plants differ entirely from the rapid work of the Phoma wilt.

Club-root, caused by a slime mold fungus (*Plasmodiophora Brassicae* Wor.) could hardly be mistaken for any of the other troubles mentioned, unless no examination were made of the distorted and enlarged roots. (Fig. 25, p. 294).

There is some possibility of confusing the work of the downy mildew (*Peronospora parasitica* DeBy) with the Fusarium wilt and black rot. Specimens of cabbage affected with the downy mildew have been received from the Lodi district (Medina Co.) this season.

Fig. 23. Showing a cabbage plant affected with black-rot, a bacterial disease caused by the organism *Bacterium campestre* (Pammel) Erw. Smith.

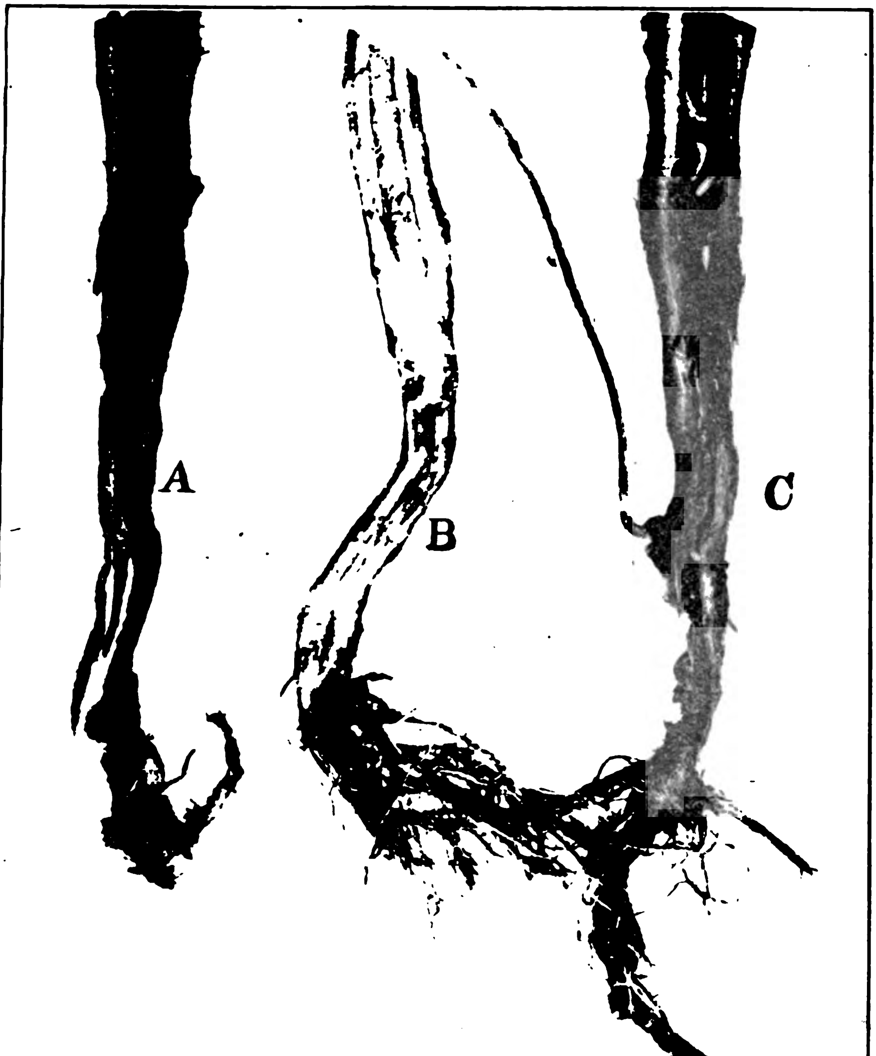

Fig. 24. "Cabbage roots injured by maggots: sections showing root badly injured both externally and internally (A), only on outer surface (B); both externally and internally, and maggots feeding within the root (C): from original Photo." This plate is used to contrast the work of maggots with that of the "Black-Leg" (Phoma wilt), see Fig. 18, page 282.

From Bul. 200: (1907), New Jersey Agr. Exp. Sta. Fig. 6 and description. "The Cabbage and Onion Maggots" [15], by John B. Smith, Expt. Sta. New Brunswick, New Jersey.

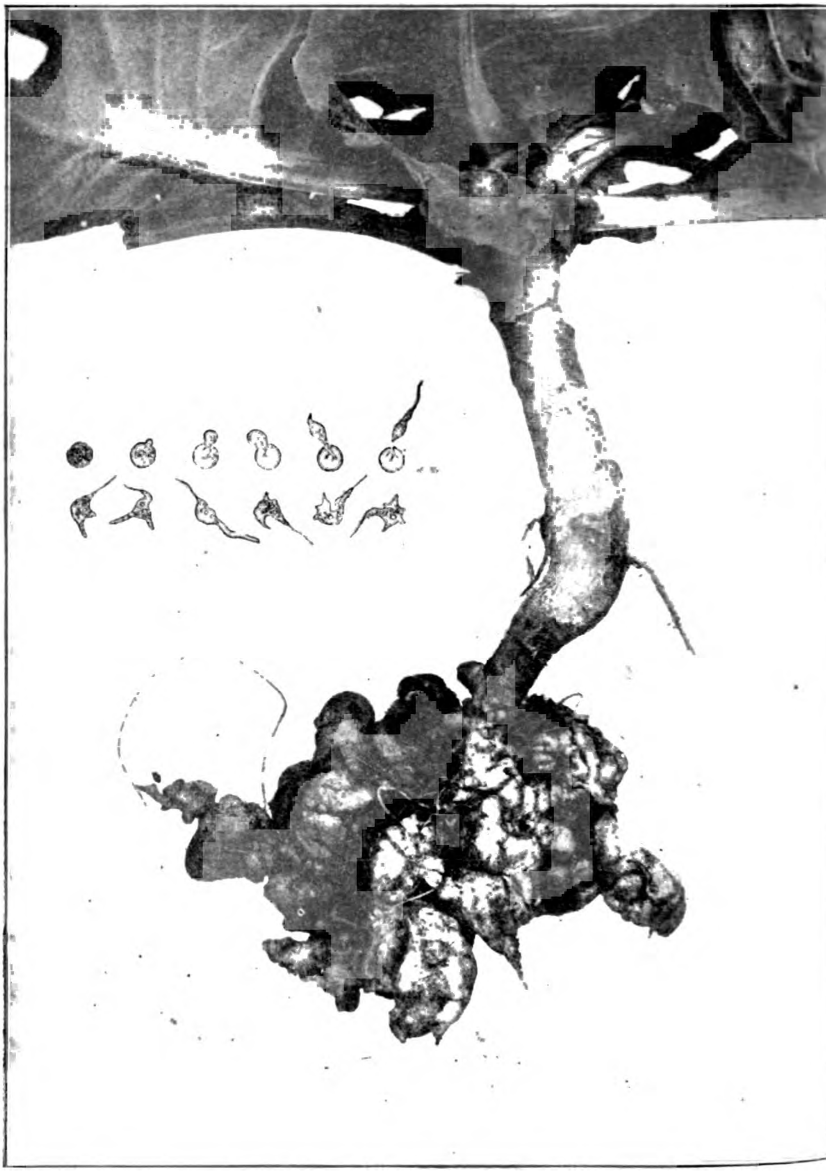

Fig. 25. Showing the club-root of cabbage, a disease caused by the slime mold *Plasmodiophora Brassicae* Wor. The development of the plasmodium is also shown. The latter is reproduced from a publication of the Dept. of Agr. Victoria—See Ref. 5 p. 276.

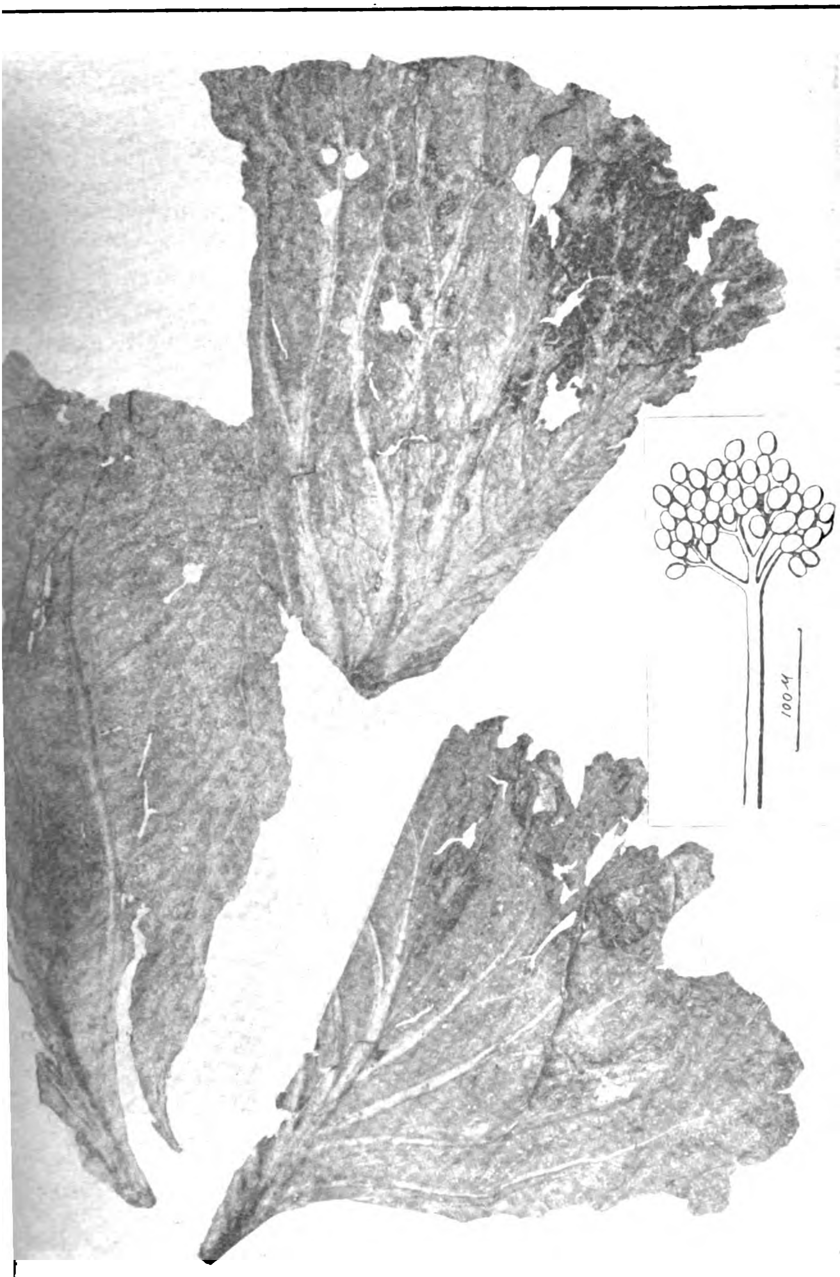

Fig. 26, Cabbage leaves showing the work and appearance of downy mildew, a fungus disease ed by *Peronospora parasitica* De By. (The fungus is shown highly magnified)

The symptoms are quite different from the Fusarium wilt, in that the leaves do not drop. The under surface of the leaf, in the infested areas, is covered with patches of the mildew. The fungus is not very conspicuous. Brown spots one-half to three-quarters of an inch in diameter are formed throughout the affected parts; large areas turn yellow and the texture of the leaf becomes very leathery. Other fungi quickly follow the work of the mildew, especially an *Alternaria* which blackens the affected areas. See the leaf in the right-hand, upper corner in Fig. 26, p. 294. Plants may become affected in the seed bed and continue throughout the whole season, but as a rule, only the older and nearly matured leaves are most severely affected.

COOPERATION INVITED

Owing to the lack of statistics giving data on the cabbage crop, much difficulty is met with in keeping in touch with the different cabbage districts. Information from several sources indicates that the crop is being taken up by farmers who have had little experience in the growing of cabbage, and much less with the many troubles affecting it. The Experiment Station invites cooperation. Assistance may be given the Station by sending in information of the acreage in each vicinity where cabbage is grown; whether the crop is on the increase or decrease, and why; the average tonnage per acre, and the value of the same; the date when cabbage was first grown on a commercial basis; whether old land responds to the crop as well as new; what diseases are prevalent and how severe each has become.

We can assist you by diagnosing the plant diseases, and by recommending treatment or measures for the control of the different troubles. Send in diseased specimens for identification. Ask for Bulletin No. 214, "A Brief Handbook of the Diseases of Cultivated Plants in Ohio."

ACKNOWLEDGMENTS

The writer wishes to thank Prof. A. D. Selby for his kindly interest in furthering this work. To Messrs. John Baker. John Kline and others, of Clyde, and Guy Wickert of Fremont, together with many correspondents acknowledgment is due for the assistance rendered in obtaining data and material.

The illustrations are all those of the writer, or from material gathered by him or correspondents, with the exception of Fig. 24, from a New Jersey Station publication, and part of Fig. 25, from a publication of the Department of Agriculture, Victoria, for which credit is given in the description of these plates.

To Mr. Wm. Beeching, Jr., the Station photographer, is due credit for the photographing of Figs. 15, 16, 17, 20, 25 and 26, and for the excellent prints for all the illustrations.

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THE FUSARIUM BLIGHT AND DRY ROT OF THE POTATO

OHIO

Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., MAY, 1911.

BULLETIN 229

OHIO AGRICULTURAL EXPERIMENT STATION

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BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 229 — MAY, 1911.

THE FUSARIUM BLIGHT (WILT) AND DRY ROT OF THE POTATO

PRELIMINARY STUDIES AND FIELD EXPERIMENTS

By THOS. F. MANNS

INTRODUCTION

The potato crop in Ohio for the past thirty years has ranked high among our agricultural products. The acreage throughout this period has increased but little, if any; the average yield per acre, however, by five-year periods since 1894, shows a marked though gradual increase; the average yield per acre for the five-year period from 1894 to 1898 was 69 bushels; from 1899 to 1903, 84 bushels, and from 1904 to 1908, 90 bushels.* The greatest production was reached in 1909, when with an area of 151,611 acres, there were produced 14,511,973 bushels; an average of 95 bushels per acre.† The average acreage for the 15 years noted above was 135,314 acres. We are yet far below our possible yields.

The gradual increase in yield per acre noted above is undoubtedly attributable to many factors, chief among which are: a better knowledge of the crop's requirements; better preparation and tillage of the land; improved varieties; better storage; improved machinery; localized culture; better control of the fungus and insect enemies. In regard to these fungus and insect factors there are few crops that require closer or more prompt attention than does the potato crop. Only with the acquisition of recent knowledge has it

*Ohio Agr. Statistics, Rep. Ohio Dept. Agr.
†Rep. Ohio Dept. Agr. July, 1910.

become possible to control these pests properly; this is particularly true of the fungus diseases. Among these are included the scab,[1] the early blight, the late blight, the bacterial blight, the rosette (*Rhizoctonia*), the black-leg, and the Fusarium dry rot and blight. The Fusarium blight has only been recognized as a field trouble in this state since 1909. The object of this bulletin is to present to the potato growers of Ohio a preliminary statement of the nature of this disease, together with methods which may be used in its control.

THE RECOGNITION OF THE FUSARIUM DISEASE AS A FIELD TROUBLE AT WOOSTER

The season of 1909 was ideal in Wayne county for a large potato yield. During the early part of July the Department of Horticulture at the Station reported a sick condition of the potatoes in one of the unfertilized plots of the wheat-clover-potato (3-crop or potato fertilizer) rotation. Examination of the area, followed by artificial culture work upon the sick plants, showed the trouble to be caused by the Fusarium fungus of potato dry rot. All the plots, 34 in number, of the potato section showed an abnormal yellowish coloring of the foliage, which symptom was followed soon after by a very premature dying of the tops. Shortly after digging the crop on this area Mr. W. A. Orton, Plant Pathologist of the U. S. Department of Agriculture, on a visit here, went over the plots in company with Prof. A. D. Selby and the writer. He recognized the trouble as being similar to that in San Joaquin county, California[2], where the disease had become a persistent and serious soil trouble. Being very familiar with the symptoms of internally infected potatoes, he readily pointed out that nearly all the tubers grown upon this field were carrying the disease. The destructive nature of the infection became more apparent when a comparison of the yields from these Station plots was made with the average for Wayne county for the same season. The Station plots averaged 69 bushels per acre and the county averaged 186 bushels. The preceding four-year average for the Station was 180 bushels, while that for the county was 101 bushels. Associated with this Fusarium blight at the Station in 1909 was a large number of the white grubs. This insect complication, because of injuries, certainly greatly favored the fungus in gaining entrance into the plants and tubers.

[1]These diseases are described and methods for their control are given in Bulletins 199 and 214 of this Station; these bulletins will be sent free upon request

[2]Cir. Bur. Pl. Ind., U. S. D. A., 23; 1909.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

PLATE I.

Tubers showing advanced stages of the "dry rot" due to the fungus *Fusarium oxysporum*. In Figs. 1, 2, and 3 the rotting is taking place at the stem end, which is evidence indicating the fungus causing the rot, entered the tuber through the tuber-bearing stem at the time when the potatoes were in the ground. Fig. 4 shows the rot at the side of the potato, indicating that the fungus of the disease entered through a bruise or other injury.

Infested soil and diseased seed are means of infecting the potato crop.

Illus. reduced 1-6: Material from L. P. Scott, Kinsman, Trumbull county, Ohio. Variety, Pres. Roosevelt. Photographed 6-4-10.

CONDITIONS THROUGHOUT OHIO

Following the investigations at this Station an effort was made to learn to what extent these conditions prevailed throughout the State. Accordingly, trips were made into the potato districts by Prof. A. D. Selby, the Botanist, Mr. J. H. Gourley, the Assistant Horticulturalist, and the writer, at that time Assistant Botanist. The first of these trips was made by the writer through several of the more important potato counties of the State, viz.: Northern Wayne, Medina, Summit, Portage, and Trumbull. The disease was observed in all the fields examined, varying from an infection of less than one percent to that of a premature dying similar to the conditions at the Station. Specimens of sick plants and tubers were brought into the laboratory and artificial cultures showed them to be infected with a Fusarium similar to that which causes dry-rot of potato. Indeed the tubers obtained from sick plants from several of the fields were, at the time of gathering, far along with the dry-rot disease.

Later trips made by the writer into the northwestern counties and by Prof. Selby and Mr. Gourley into the eastern, southern and southwestern parts of the State showed the conditions to be quite general, but varying in each locality from a light infection to a severe or premature dying.

AN OUTBREAK OF A SIMILAR DISEASE IN EUROPE

In Europe since 1905 the journals of plant pathology have been filled with many articles on a potato disease which is there designated by the Germans, "blattrollkrankheit", that is, "leaf-roll disease". The symptoms given are quite identical with those of the disease which prevails throughout Ohio. However, in Europe the plant disease specialists are somewhat at variance as to the specific cause of the disease. Appel,[3] a most able student of potato diseases, is inclined to ascribe the cause to a parasitic fungus. Sorauer,[4] on the other hand, thinks the trouble is physiological, being brought about by certain enzymatic discrepancies. Kornauth and Reitmar[5] in a recent publication have reviewed some 46 European articles on this disease in which the writers are widely at variance in their conclusions. Kornauth and Reitmar made microscopic and cultural studies upon some 56 specimens of infected material sent to them from different parts of Europe, with the result that the microscopic examinations showed all to contain a Fusarium, while the artificial cultures brought out a Fusarium from 60.7 percent of the specimens.

[3] Appel, O., Zeitschr. f. Pflanzenkrank. 17:307;1907.
[4] Deutsche landw. Presse 1908.
[5] Kornauth, K. Reitmar, O., Zeitschrift f. d. Landwirtschaftliche Versuchswesen in Oesterreich 97-125; 1909.

A number of the European investigators have demonstrated that the seed potato is a means of spreading the disease, and many recognize the trouble as a more or less persistent soil infection. Meteorological conditions receive a great deal of emphasis as factors in bringing about the disease which prevails in Europe.

HISTORY OF THE FUSARIUM DISEASE OF POTATOES AS A STORAGE ROT AND AS A FIELD TROUBLE

The dry rot of potatoes has long been known as a storage trouble. At intervals since 1824 there has been found associated with this rot by different investigators a fungus of the genus Fusarium, which has been variously designated. One of the earliest investigators to record the presence of a Fusarium with the dry-rot of potato, according to Smith and Swingle[6], was Schlechtendal in 1824; he named the fungus *Fusarium oxysporum*. Smith and Swingle were the first workers to settle definitely the relationship of the Fusarium to the cause of potato dry-rot and stem blight. On account of priority in the use of the name they have adopted Schlechtendal's designation of the Fusarium, viz., *Fusarium oxysporum* Schlecht. The writer will use this scientific terming of the fungus, though he is quite aware that *Fusarium solani* is being extensively used.

The history of the disease as a field trouble is of comparatively recent record. Stewart,[7] of New York state in 1896 described a field trouble of the potato under the heading: "Another Stem-Blight of Potatoes". His careful description of the symptoms shows that he well recognized the disease as quite distinct from other potato troubles with which he was familiar. He failed, however, to work out the specific cause. After carrying out some carefully planned experiments upon land which previously had not grown potatoes for at least ten years, using "badly diseased tubers", which he planted adjacent to healthy seed, the former producing a yield at the rate of 266 bushels per acre, while the latter averaged at the rate of 305 bushels, Stewart concluded that, "the results of this experiment furnished strong evidence that the disease is not communicable, which is equivalent to saying that it is not caused by any vegetable organism."

In noting the growth of the plants from the diseased seed, Stewart writes: "Nearly every piece of 'seed' produced a plant, but many of them were slow in coming up. They appeared weak, were of diverse sizes and up to the time of blossoming, were considerably smaller than plants from healthy seed planted at the same time."

[6]Smith, Erwin F., and Swingle, Deane B., Bul. Bur. Pl. Ind., U. S. D. A. 55; 1904.
[7]Sterwart, F. C. Rpts. N. Y. Agr. Exp. Sta. 15: 1896; 16; 1897.

"It was late in July before any of the plants showed symptoms of the disease, and at the close of the season only a few had had even a mild attack. When the potatoes were dug just a few showed the characteristic blackening of the fibro-vascular bundles at the stem end."

Stewart's careful observations and work cannot be passed over lightly. A duplication of his work with badly diseased seed upon soil free from the disease will give quite similar results. It is upon badly infested soils that the disease works such havoc.

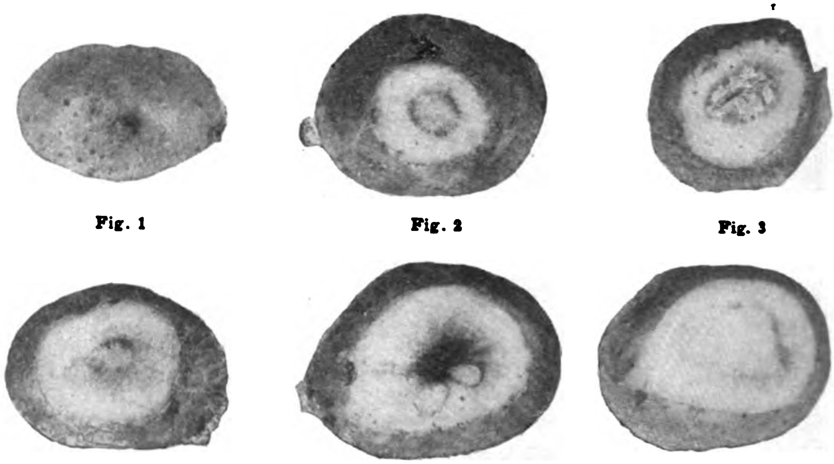


Fig. 1 Fig. 2 Fig. 3

Fig. 4 Fig. 5 Fig. 6

PLATE II

Showing sections across the stem end of tubers from plants which had prematurely died through infection with *Fusarium oxysporum*. The brown, circular spotting shows the presence of the parasitic fungus. All of these tubers, except the one in Fig. 6, are carrying the disease.

By cutting away the stem end to a depth of 1-2 to 3-4 inch, and following this with the formaldehyde treatment, such tubers may be used to produce a disease free crop, providing they are planted on non-infested soil.

Illustration natural size. Material from G. W. Leonard, Tallmadge, Summit county. Photographed 6-25-09.

Since Smith and Swingle's work, Orton[8] has studied the disease as a field trouble in 1908 in San Joaquin county, California, where the soils have become so badly infected with the disease as to cripple the potato crop seriously. Again in 1910[9] Orton calls attention to the "wide-spread and destructive" nature of this disease in the United States.

During the past season the Department of Botany of this Station has sent out two press bulletins[10] upon this disease; in the first, calling attention to the nature of this disease as a seed infection, and in the second, noting the field symptoms of the disease.

[8]Orton, W. A. Potato Diseases in San Joaquin Co. Cal., Cir. Bur. Pl. Ind. U. S. D. A. 23: [illegible].
[9]Orton, W. A. Science N. Ser. 31 (1910) No. 802, p. 751.
[10]Press Buls. Nos. 311, 316; 1910 Ohio Agr. Exp. Sta.

THE FUSARIUM DISEASE OF POTATOES; BOTH A FIELD AND A STORAGE TROUBLE.

SYMPTOMS IN THE FIELD

The outbreak of the disease at the Station in 1909 was in no way complicated with early or late blight, hence the symptoms of the disease stood out very distinctly. By recalling observations of previous years we were able to correlate certain irregular behavior of the potato crop in the past with that of the 1909 conditions at the Station.

On badly infected soils the disease is characterized as follows: The stand is uneven, though few of the hills are missing The early growth is somewhat slow. When the plants reach a height of 10 to 14 inches, there is an apparent cessation of growth. The first indication of the disease is usually conspicuous at this time. The preliminary symptoms are a light green color of the foliage, particularly the lower leaves; this is accompanied during the heat of the day by a partial wilting and an inward and upward rolling of the upper leaves. The color gradually changes to a sickly yellow, which slowly and evenly covers the affected vines. The wilting and rolling of the leaves extends to all parts of the affected plants.

In the varieties with heavy dark-green foliage the wilting and "rolling-in" symptoms are not always accompanied by marked changes in the leaf coloration.

As the disease progresses the field takes on a mottled yellow to light green color. The growth of the foliage is greatly restricted. The wilting becomes more pronounced; there is associated much tip-burn owing to the failure of the leaflets to fully recover at night from the severe wilt of the mid-day. The lower leaves of the affected plants are first to die; (See Plate IV, plant at the right) they fall into a vertical position along side the stem, hanging by only a small part of the bark below. The upper leaves usually do not drop, but droop over upon wilting. Occasional hills will show only one or two vines afflicted. Plants which early succumb to the disease pull up easily, manifesting a badly rotted condition of the root. As a rule, the blighted stems do not fall, but remain quite erect except for the drooping top. (See Plate VII, Fig. 2.)

A careful examination of the underground parts of the afflicted plants in their early symptoms reveals a number of pathological conditions. When the soil is thoroughly sick many of the root hairs and smaller secondary roots are entirely destroyed. Parts of the main root and many of the larger secondary roots manifest a vitreous, sickly, watery, aspect, instead of the clear white of healthy

roots. Cross sections of the large roots and the stem at a level with the ground or below show some or all of the vessels to be of a brown or dull gray discoloration.

Following the marked yellowing of the fields a premature ripening or dying of the plants sets in. The life of the crop is shortened fully three to six weeks. The tubers are undersized and the yield is materially reduced.

The subtle and persistent nature of the disease is such as to mislead even the plant pathologist. The progress of the disease is greater in certain areas than in others, due probably to several different factors, such as previous infection being uneven, irregular drainage, different soil conditions, etc.

THE DISEASE A ROOT INFECTION

The disease makes its attack by way of the root system. Nearly all such root infecting parasites are more or less persistent soil organisms. We have in this Fusarium of potato blight no exception to this rule.

The growth of foliage put out by plants is determined wholly by the extent of the root system. When the roothairs and smaller secondary roots are destroyed by a fungus disease the plant adjusts itself to these conditions by a cessation of the foliage growth, and attempts to recover itself by putting out an additional root growth. However, with this particular fungus, it is not restricted to an attack of the root hairs or secondary roots, but it readily penetrates the main root, killing the cambium and blocking up the water conducting vessels. (See Plate VI and description.) Artificial culture work upon the roots of sick plants showed them to be abundantly infected with the parasitic fungus. The root hairs and secondary roots were badly destroyed. It is this crippling and destruction of the root system that brings about the rapid premature dying of the crop. The stems above the ground show little or no indication of the fungus until the plant has nearly succumbed to the disease. Later, however, the fungus may produce a copious growth of spores (*macroconidia*) for a considerable distance up the wilted stem.

The infection of the new crop takes place directly following the dying of the root system. The fungus penetrates the tuber-bearing stems and follows these into the tuber. After a short penetration of the new potato the work of the fungus takes place much more slowly. Usually at digging time the depth of penetration seldom reaches deeper than one-fourth to one-half inch. In some of the more susceptible varieties, however, the stem end may be rotted to a depth of one inch or more.

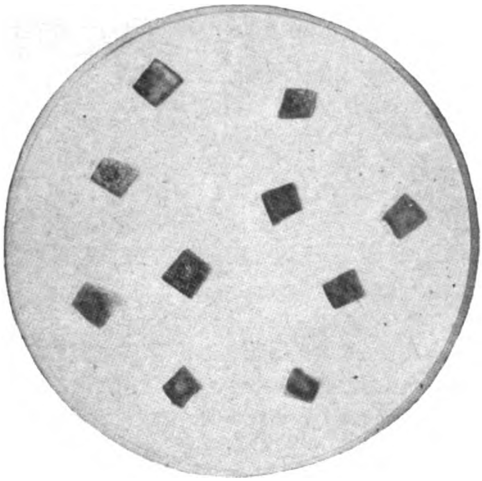


Fig. 1

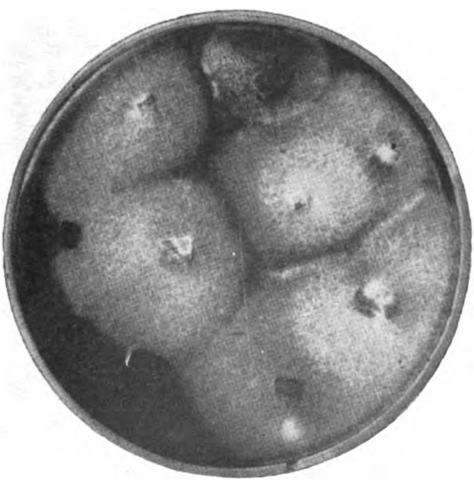


Fig. 2

PLATE III

Showing how the presence of the Fusarium fungus, which causes premature dying in the field and dry-rot in storage, may be demonstrated in pieces from the stem-end of infected tubers, by means of artificial cultures in the laboratory.

Small sections of the brown area from the stem end of infected tubers (See such tubers as Figs. 2, 3 or 4 of Plate II) will, when placed upon an artificial medium, bring out in three or four days the fungus (mold) which is responsible for the disease.

Fig. 1. Shows the pieces of tubers just after being placed in a culture dish.

Fig. 2. Shows the growth of the fungus from the pieces of potatoes eight days after being placed in the dish. Seven pieces of the tubers are showing the white Fusarium fungus, and one piece at top of the plate is showing an associated fungus (a Vermicularia sp. see p. 315).

The laboratory culture method is a sure way of demonstrating the presence of the fungus.

THE DISEASE AN INTERNAL INFECTION OF THE TUBER

With this internal infection of the new crop we have come to one of the most important facts regarding the disease. The depth of infection varies from that of a very shallow, light yellowing of the vessels at the stem end, so inconspicuous as to be entirely passed over by the layman, to that of a pronounced blackening of the vessels to a depth of one-half inch, or indeed later it may extend clear through the tuber. (See Plates II, VIII, IX and X.) When the infection is very light the presence of the parasitic fungus can be determined only by microscopic examination, or preferably by means of artificial cultures (See Plates II and III, showing shallow infection, and the determination of very light infection by cultures.) This internal infection may be very marked and yet in no way impair the superficial appearance of the tubers, nor even the keeping qualities when the potatoes are placed in proper storage. (See Plates IX and X showing potatoes that had passed through winter storage.) Indeed, it is this inactive or dormant internal infection during storage which is the means of bringing about the widespread distribution of the disease. Under improper storage much of this infection becomes so active as to cause a high percentage of dry-rot, an extreme condition in which the potatoes are of no value for food or seed. The importance to the grower of being able to recognize this internal infection cannot be over-emphasized. With the seed lies the only possible opportunity of controlling the dissemination of the disease. The appearance of this infection in the tubers varies slightly in different varieties. As a rule the ring of vessels becomes deeply blackened wherever the fungus penetrates. (See Plate IX, the three tubers above.) Sometimes, however, the fungus is not confined strictly to the vessels, but may penetrate at random throughout the flesh of the tuber. This peppered appearance was noted in several of the early varieties and was identified as the same disease by means of artificial cultures. (See Plate IX, the four tubers below.)

A CAUSE OF DRY-ROT IN STORAGE

Since the recognition of the Fusarium as a cause of a blight in the field, and of an internal infection of the tubers, pathologists have lost no time in learning of the progress of this internal infection in storage. As a dry-rot the disease makes its greatest headway under high temperatures in the presence of considerable moisture. For these reasons the storage of potatoes in warm cellars under dwellings is a practice certainly not to be recommended. The writer carried out experiments on the progress of the disease with

everal different varieties under various conditions, viz., high temerature (60° to 80° Fah., laboratory conditions) and very dry; iese same conditions with moisture; also under cool temperatures, 5° to 55° Fah., and very dry; and the same temperatures with ioisture. Also under storage conditions varying from 36° to 40° ah. The disease at these lower temperatures apparently made ttle, if any, progress. However, at 45° to 55° Fah., the disease eveloped gradually and caused much rot, especially where placed ith moisture. Moisture favors bacterial and fungus associion, finally culminating in much wet and soft rots. High mperature is the chief factor in favoring the Fusarium of dry-rot. here is sufficient moisture within the tuber to meet the demands the fungus, and its work at temperatures between 60° and 80° ah. is very rapid. (See Plate I.) Rot usually takes place first at ie stem end, indicating that it is a continuance of the infection in ie field. (See Plate I, Figs. 1, 2 and 3.) However, occasionally irough insect injury, bruise, or contact of a rotting tuber, infection ay take place and the rot develop at other points (See Plate I. ig. 4.)

THE POSSIBLE LOSSES IN STORAGE

The greatest losses in storage from this disease take place in ellars under dwellings, or in outbuildings where a low temperure cannot be maintained. That this loss throughout the state is small item is evident. The writer has done very little in gatherg exact data upon these losses. Several cases in which the losses om this disease were of an extreme nature have come under his servation. In Portage county, in 1909, the crop from an infested eld, the potatoes of which were so badly infected internally that ie writer advised the grower to sell rather than place in cellar orage, came through with heavy loss. The grower informed us the spring of 1910 that "out of every 100 bushels we got 15 to 20 ishels of rot, mostly dry rot."

In 1908 out of 10 bushels the writer placed in his cellar for inter use, over one bushel had to be thrown out from dry-rot. he conditions for storage in this case were not favorable, as there as only a board partition between the furnace and the storage om.

The work of the dry-rot in improper storage causes an excess moisture, due to the drying up of the rotting tubers. This cess moisture condition, together with the added facility with hich bacteria and decay fungi may enter the already infected bers, brings about much complication in the form of soft or wet ts, for which the Fusarium disease is primarily responsible.

Under the average cellar storage conditions it is quite safe to estimate the loss from dry-rot and its complications at from one to five percent.

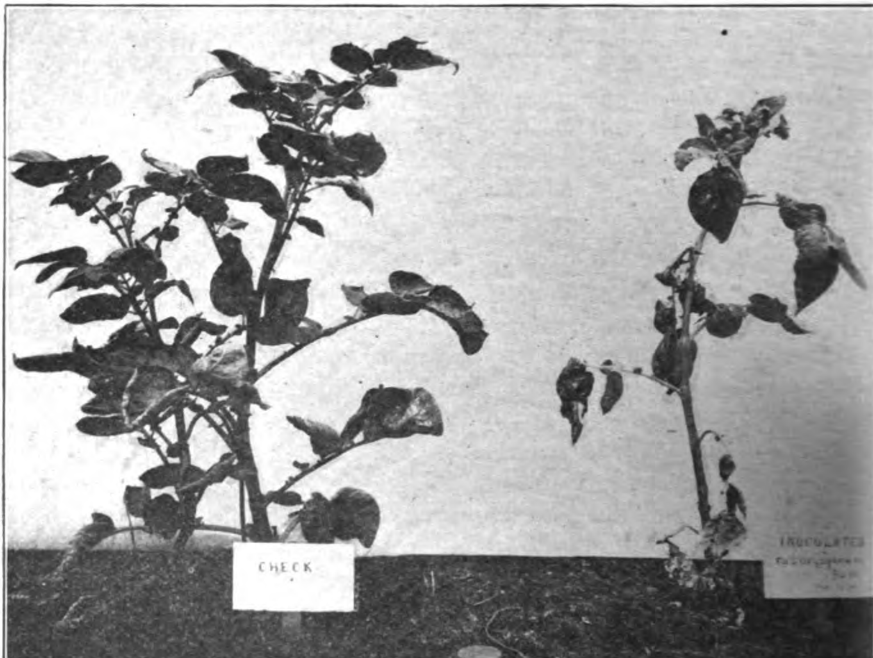


PLATE IV

Showing, in the plant at the right, the characteristic yellowing and wilting nature of the [illegible] disease on an artificially infected plant of the Carman No. 3 variety. Varieties having medi[illegible] green foliage usually show yellowing of the lower leaves as the first symptom of the [illegible] infection. However, those varieties with heavy dark green foliage usually show a less[illegible] yellowing of the leaves, but the inward and upward rolling symptoms on the leaves are [illegible] marked than on the lighter colored varieties.

The plant at the left is not infected. Note the darker colored foliage. Inoculated 1-4-1[illegible] graphed 3-7-10.

DIRECT LOSSES FROM USING INFECTED SEED

The amount of loss occasioned by using infected seed can only be determined by growing such seed upon soils free from the disease, and along side of which is planted seed of the same source and variety which is not carrying the disease. During the season of 1910 the writer carried out, with the assistance of others, experiments of this kind upon nine different varieties, which differed greatly in the amount and the depth of the infection they carried. (See Plates IX and X.) In all these experiments the difference between the yields from the infected seed and seed of the same source and variety free from the disease was not as great as one might expect. Depending directly upon the amount and the depth of the infection in the sick seed, the yields from the healthy seed showed gains of

from less than one percent up to 42 percent. (See Plates IX, X and XI.) The important question, however, that one should put to himself is not how much am I saving in this crop by not planting sick seed, but what will it mean for the future of the potato crop to infect my fields with this persistent soil parasite? Both questions are worth considering, but the latter is by far the more important. In dealing with pernicious soil organisms, they should be considered far more subtle and disastrous than are noxious weeds. The latter may be eradicated by labor and perseverance, while the former often require us to drop from our rotations one of our most profit. able crops. Such is the history of flax in the north-western states, and of cabbage in certain parts of our own state. It often requires 10 to 15 years of special cropping before such a disease is eliminated from the soil.

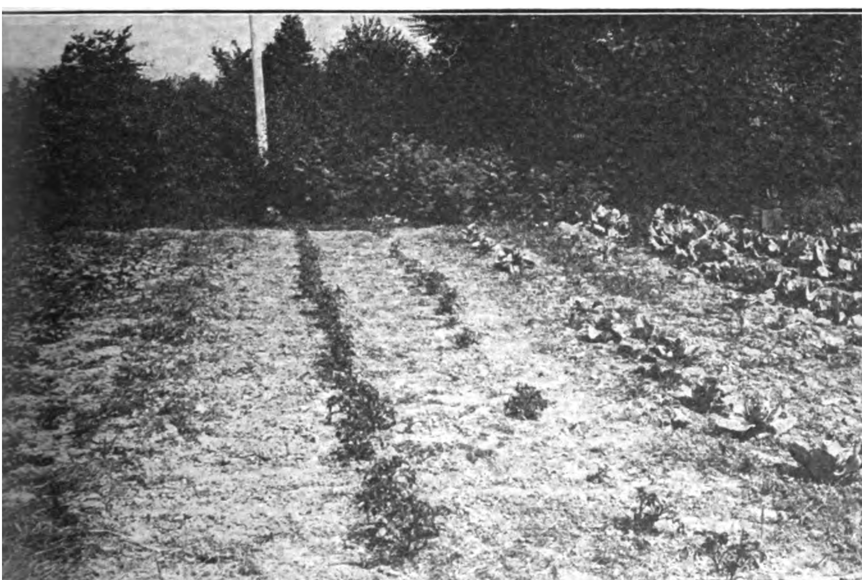


PLATE V

Showing the effects of the Fusarium disease on the potato stand. The row at the left was not nfected. The row at the right was infected by placing thin slices of dry-rot infected tubers beside healthy seed. The stand was much reduced and very much slower in coming. In this experiment he potatoes were planted late, June 25, 1910, and the intervening drouth was a factor favoring the work of the disease. The Fusarium disease is a factor in bringing about a reduced stand.

THE LOSSES FROM SICK SOIL CONDITIONS

It is the contention of the writer that in this Fusarium blight we have the most persistent and destructive disease factor with which the Ohio potato grower has to contend. Its subtle work in the past, though greatly reducing our yields, has been entirely over-

looked. The disease is of such a nature that it works great havoc with the root system of the plant several weeks before any definite above-ground symptoms are manifest. It is this crippling of the root system that brings about such premature dying, when the slightest adverse conditions set in.

The writer had an excellent opportunity during the past season (1910) to study the season's growth upon two fields of potatoes, one in which the soil was generally infected, and in another in which only a little more than three percent of the vines showed symptoms of the disease. The badly infected field was part of a three-year rotation of wheat, clover and potatoes, being used for a fertilizer test, and hence was variously fertilized, one-third of the area receiving no application whatever. The non-infected field had grown crops of wheat continuously, during the five previous years; manure was used to some extent, but no commercial fertilizers. The potato crop was also not fertilized in 1910. The strength of soil, the previous cropping, the stand and other factors would seem to favor the three-year rotation. The variety used in both instances was Carman. When the severe midsummer drouth set in, the potatoes on the infected land apparently ceased to grow; they assumed a mottled, sickly yellow color and in three to four weeks later showed premature dying, and all the evidence of maturing. On the other hand, the potatoes on the non-infected soil held their color and general appearance well during the drouth, except the few vines which were infected, and upon the appearance of the fall rains, matured a medium crop. The potatoes on the infected field yielded 90 bushels per acre, while those on the uninfected land reached a yield of 125.6 bushels.

As previously noted (p. 300) the above mentioned three-year rotation in 1909 averaged only 69 bushels, while the average for Wayne county was 186 bushels.

Observations made by the writer in the northern and northeastern parts of the state showed conditions quite identical with these.

It would appear from this information that potato growers not only must look well to the condition of their seed, but if their soils are already badly infested with the Fusarium disease, they must keep the potato crop off, and work the disease from the soil by the use of grain, hay and other crops; tomatoes must be excepted, as it seems quite probable they are attacked by the same fungus. Just how long the disease will persist under other cropping than potato is not known. It is safe to say that five to six years will at least be required.

A STUDY OF THE SEED POTATO CONDITIONS IN 1909 AND 1910

SEED FROM DIFFERENT PARTS OF THE STATE

Considerable effort was made to learn how much of the seed throughout the state was infected with the Fusarium fungus, and the percent and depth of infection in each sample. With this object in view many samples were examined by cutting sections with the knife from the stem end of the tubers. This method was substantiated throughout by artificial culture work.

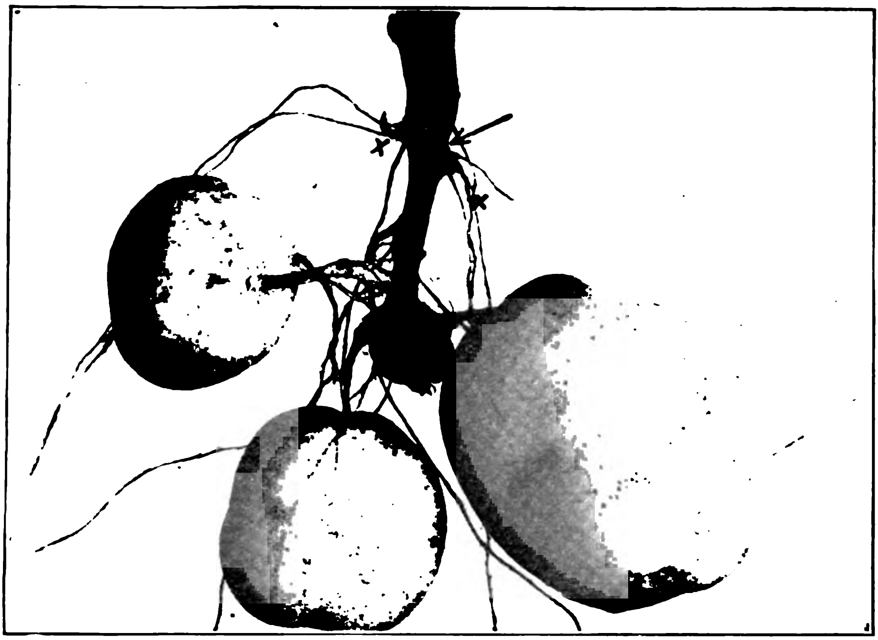


PLATE VI

Showing the actual size of the tubers produced by the artificially infected plant in Plate IV. The work of the fungus destroys the roots and shortens the life of the plant, thereby causing a crop of undersized immature tubers, which have a tendency to peel or shed the skin.

Note the lesion (diseased part) pointed out by the arrow, and also the roots destroyed at the points marked X.

The seed potatoes throughout Ohio are infected to a much greater extent than would have been supposed. This indicates that much of our potato land is already carrying the fungus to a greater or less amount, and as a result our yields are probably being reduced considerably.

Where the infection is marked as plainly as that indicated in Plates II, VIII, IX and X, the diagnosis by knife sections and eye inspection may be relied upon. There are, however, many cases where the infection is so shallow and the coloring of the vessels at the stem end so slight as to make the diagnosis by knife sections doubtful; in such cases accurate determination of the presence of the fungus can be made only by artificial cultures or microscopic examinations (See Plate III).

In table I is given a summary of the examinations made of potato tubers and plants in 1909 and 1910.

TABLE I

A SUMMARY OF EXAMINATIONS MADE FOR FUSARIUM ON SEED POTATOES AND PLANTS IN 1909 AND 1910

County	Town	Variety	Material	Amount of Fusarium Infection and Remarks
Ashtabula.	Andover		Plants	Disease bad in vicinity
Athens	Sharpsburg	Early Ohio	Tubers	76 percent, shallow to deep infection.
Athens....	Sharpsburg	Early Ohio	Tubers	100 " " " "
Athens....	Sharpsburg	Early Ohio	Tubers	80 " " " " "
Auglaize ..	New Knoxville		Tubers	40 percent, infection not deep.
Coshocton.	Coshocton		Plants	All Fusarium blighted.
Cuyahoga..	Cleveland		Tubers	Badly Fusarium infected.
Erie........	Berlin H'ts	Billion Dollar	Tubers	50 percent, infected ⅛ in. or more.
Erie........	Berlin H'ts	Nationals	Tubers	11 " " " " " "
Erie.......	Berlin H'ts	Noxalls	Tubers	10 " " " " " "
Erie.......	Berlin H'ts	Green Mt.	Tubers	5 " " " " " "
Erie......	Berlin H'ts	Sir Walters	Tubers	8 " " " " " "
Franklin .	Columbus	Seneca Beauty	Tubers	22 percent; infection shallow.
Franklin ..	Galloway	Ohio Jr.	Tubers	Some infected.
Franklin .	Galloway	Gold Coin	Tubers	Badly infected.
Hamilton..	Cmp Dennison		Tubers	66 percent; infection not deep.
Holmes ...	Mt. Eaton		Tubers	53 percent; infection not deep.
Huron	New London		Plants	All plants sent in were infected. writer says 25 percent of crop infected.
Huron	Norwalk	Mixed	Tubers	81 percent; infection shallow.
Huron	Norwalk	Early Variety	Tubers	50 percent; deeply infected.
Huron	Norwalk	Early Fortune	Tubers	100 percent; infection shallow.
Lake......	Painesville		Tubers	Some Fusarium infection.
Logan. ...	West Liberty		3 Plants	Two infected with Fusarium.
Logan.....	West Liberty		4 Plants	Two " " "
Logan	West Liberty		5 Plants	Three " " "
Lorain... .	Grafton		2 Plants	One " " "
Medina	Seville		3 Plants	Two Fusarium blighted.
Medina ...	Brunswick		3 Plants	Two Fusarium blighted.
Medina	Lodi		Plants	Fusarium blighted; premature dying bad
Medina	Medina	Pres. Roosevelt	Plants	Fusarium blighted; much dying.
Medina. ..	Medina		Field	1 percent, premature dying.
Medina	Medina		Field	Fusarium blighted. premature dying bad
M'ntgomry	Dayton		2 Plants	Both dead from Fusarium.
M'ntgomry	Englewood		Plants	All Fusarium wilted.
Morrow	Marengo		Tubers	18 percent; deeper than ⅛ in.
Ottawa....	Port Clinton		Tubers	100 percent; some infected deep.
Portage....	Mantua		Tubers	87 percent, about ¼ in. deep.
Portage....	Garrettsville	Carman	Being ship'd	7 percent, ¼ inch or less.
Portage....	Garrettsville	Irish Cobbler	Field	Fusarium blight bad.
Portage...	Garrettsville		Field	3 percent prematurely dying.
Portage....	Freedom	Million Dollar	Field and Tubers	Considerable premature dying. Potatoes 40 to 80 percent infected.
Sandusky..	Fremont		7 Plants	Four Fusarium blighted.
Sandusky..	Clyde	Carman	Field	Fusarium blight bad.
Seneca.....	Tiffin		Plants	Fusarium blighted.
Seneca.....	Tiffin	Gold Coin	Tubers	14 percent infected ⅛ inch or more.

TABLE I—Continued

A SUMMARY OF EXAMINATIONS MADE FOR FUSARIUM ON SEED POTATOES AND PLANTS IN 1909 AND 1910

County	Town	Variety	Material	Amount of Fusarium Infection and Remarks
Seneca....	Tiffin	Sir Walters	Tubers	10 percent infected ⅛ inch or more.
Seneca....	Tiffin	Ea. Petasky	Tubers	76 percent shallow infection.
Seneca....	Tiffin	Selection 807	Tubers	100 percent shallow infection.
Seneca.....	Tiffin	Lilly White	Tubers	100 percent shallow infection.
Stark......	Louisville		Tubers*	Badly infected with dry-rot.
Shelby.....	Sydney		Tubers	100 percent infected about ¼ in deep.
Summit....	Tallmadge	Sever'l varieties	Field	Badly Fusarium blighted, prem. dying 5 to 10 percent, dry-rotted at stem end at time of digging.
Summit....	Tallmadge	Carman	Tubers	
Summit....	Tallmadge	Sir Walters	Tubers	2 percent dry-rotted at stem end.
Trumbull.	Kinsman	Irish Cobbler	Plants	Some infection.
Trumbull..	Warren		Fields	Much premature dying from Fusarium
Trumbull..	No. Bristol	Harris Snowball	Tubers	100 percent infection shallow.
Trumbull..	No. Bristol	Sir W. Raleigh	Tubers	83 " " "
Trumbull..	No. Bristol	Green Mountain	Tubers	87 " " "
Trumbull..	No. Bristol	Pan American	Tubers	100 " " "
Trumbull..	Kinsman	Pres. Roosevelt	Tubers	52 percent deeper than ¼ in. (See Pl. X)
Wayne	Smithville	Gold Coin	Plants	All infected with Fusarium.
Wayne ...	West Salem		Plants	50 percent infected.
Wayne	Smithville	Gold Coin	Field	4 percent infected.
Wayne	Wooster	Pres. Roosevelt	Tubers	22 percent infected, shallow to deep.
Wayne	Wooster	Carman, O. A. E. S. sick field	Tubers	92 percent internally infected.
Wayne ...	Wooster	Carman, O. A. E. S. sick field	Tubers	62 percent by artificial cultures.
Wayne	Wooster	Carman	Tubers	60 percent; seed used in 3 yr. rot. (See p. 300)
Wayne	Wooster	Green Mountain	Tubers	Some infected ⅛ to ¼ in. deep.
Wayne	Wooster	Whiton's White Mammoth	Tubers	Many " " " " " "
Wayne	Wooster	Irish Cobbler	Tubers	Badly infected at stem end.
Wayne ...	Wooster		Tubers	100 percent; infection shallow.
Wayne	Wooster		Tubers	100 percent; infection shallow.

*From storage

From the examinations given in Table I it is quite plain that the disease is generally distributed throughout the state. The heavier losses come from planting the potato crop on soils previously infested, that is, upon areas which may be designated as "potato-sick. (See Plate XI.)

CULTURE WORK AND ARTIFICIAL INOCULATIONS

No difficulty is experienced in taking the parasitic organisms from the infected tubers and plants. Pieces of the infected potato, if properly surface-sterilized, will, when placed in culture dishes on any of the common nutrient media, bring out the fungus readily in two or three days. The preliminary growth is white and cottony. It is common to find associated with the Fusarium, and likewise penetrating the tuber sometimes to a depth of one-fourth to one-half inch, a fungus of the genus *Vermicularia*. (See Plate III and description). In potatoes which, by means of artificial cultures, showed a Fusarium oxysporum infection of 62.8 percent, the Vermicularia was present to an extent of 10.3 percent; this latter

infection coming as a rule only from pieces of tubers which also gave a Fusarium growth. The relation of this Vermicularia to the Fusarium blight disease has not been fully established, though a considerable amount of inoculation work has been carried out with and without its association. When used alone it brings about no disease symptoms. If it assists any in bringing about the disease, its work is that of a semi-parasite which follows the openings made by the Fusarium. It is almost invariably present on the under ground stems and roots of sick plants in the field, and upon tubers which are carrying internally the Fusarium fungus, showing plainly by means of the hand lens at the point of the stem connection. The writer has many times taken it from internal parts of the roots and underground stems of potato plants which were showing only the first symptoms of the Fusarium blight.

To determine whether the Fusarium found in the blackened vascular ring is identical with the Fusarium of dry-rot, and also whether each of these causes stem blight, the writer separated the organisms from the two sources, carried them through artificial cultures, and also carried out artificial infection experiments. The cultural characteristics were apparently identical. In the infection work both of the organisms were wilt producing, bringing about symptoms quite typical with that of the Fusarium blight in the field. (See Plate IV, potato at the right.)

Artificial infections were brought about in a number of ways. Slight injuries of the roots or knife incisions in the presence of the organism brought about the most rapid infections. The organism is, however, productive of infection in the absence of any root disturbance or stem injury, as was shown by a number of experiments.

WORK WITH SICK SOIL IN THE GREENHOUSE

In order to demonstrate whether the disease is an active and persistent soil parasite or not, a quantity of the infected soil from the diseased area of Plot 22 of the three-year rotation—the field which did so poorly in 1909—was brought into the greenhouse. (See p. 300 and also Plate II.) A number of experiment were carried out with this infected soil, the most important of which was the following:

In a bench 4 ft. by 16 ft. containing eight inches of thoroughly sterilized soil* there were planted potatoes of three different varieties, which were clipped free from the Fusarium infection and then treated in formaldehyde. This treatment gave assurance that

*The sterilizing process consisted of two thorough drenchings with a formaldehyde solution, made of one pound of formaldehyde in 30 gallons of water, and used at the rate of one gallon per square foot.

the seed was not carrying infection. The varieties used were Carman No. 3, Irish Cobbler and Whiton's White Mammoth. In order to infect certain rows without greatly modifying the fertility factor, a small quantity of the sick soil was mixed thoroughly in each hill to be infected In the infected hills the disease came on slowly, but very conspicuously. The marked yellowing of the infected plants contrasted very strongly against the dark green of the non-infected plants. The disease came on much more definitely under the sick soil infection than it did where pure artificial cultures were used without incisions or root injury. The great difference between sick soil infection, and that from pure cultures or even internal seed infection, is that in the use of sick soil the roots are attacked at practically every point, while with pure cultures, or seed internally infected, the fungus attacks only in close proximity to the main root, while most of the secondary roots and the root hairs remain healthy. The writer is inclined to believe that this organism is slower to penetrate through the soil than are certain others of the genus *Fusarium* with which he has worked, for example, the Fusarium of flax wilt, and the Fusarium of cabbage wilt. On the other hand, it is readily distributed by the cultivation during the season.

FACTORS WHICH INFLUENCE THE PROGRESS AND DISSEMINATION OF THE DISEASE

METEROLOGICAL CONDITIONS

As previously noted, p. 302, in Europe much has been said in regard to the influence of drouth, excessive moisture and high temperatures upon the progress of the disease. From observations made, it seems quite apparent that drouth hastens the yellowing symptoms of the disease. The writer, however, is quite undecided as to the influence this factor has upon the activity of the fungus causing the disease. In the history of the disease at the Station, the severest attack occurred during the most favorable season we have had in a long time, viz., in 1909. The temperature and rainfall that season were very equitable, as is shown by Table II, p. 319.

The average yield also for Wayne county in 1909 shows that the season was conducive to an excellent potato crop. The average yield for 1909 was 186 bushels, which was 85 bushels higher than the average for the four preceding years. The three-year rotation at the Station in 1909 averaged only 69 bushels, which was 110 bushels below the average yield for the four preceding years. From his observations the writer is of the opinion that as far as reducing the yield is concerned, the fungus will average in sick fields as great a percentage in reduction under favorable conditions as under drouth.

Fig. 1

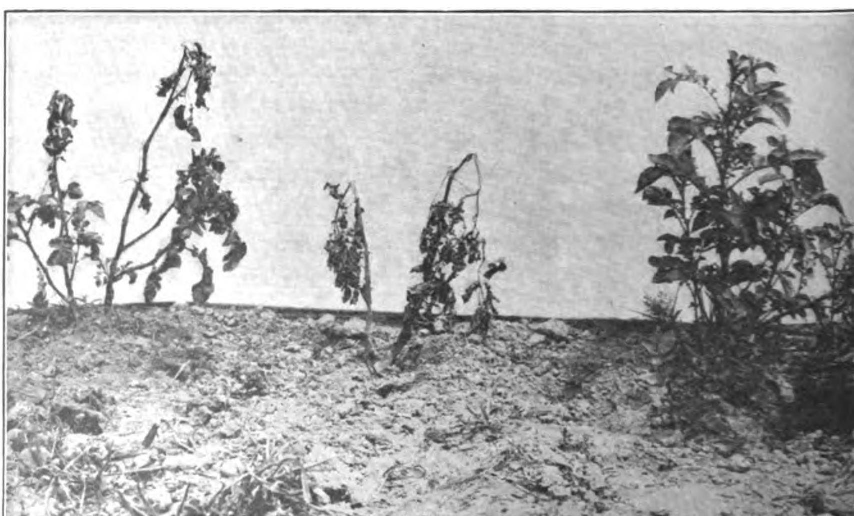


Fig. 2

PLATE VII

Fig. 1. Showing a potato rotting in the soil from the Fusarium disease Instead of being in this instance a "dry-rot", it was a typical case of "wet rot."

Whenever potatoes are placed in a warm, damp storage they go to pieces quickly from this disease; the fungus often showing on the surface as patches of a white, moldy growth. In damp storage, bacteria early become associated with the Fusarium disease, causing wet, soft rots. Storage cellars should be kept cool, dry, and well drained. Burying (pitting) in the field is more satisfactory than most cellar storage for seed purposes. Material from M. E. Yonker, Mantua, Portage county, Ohio.

Fig. 2. Showing premature dying in the field on an area which has become infested with the Fusarium disease. (See Pl. XIII). It is impossible to grow a maximum crop on infected soils. The rotation should be lengthened so that the potato crop will not come oftener than once in four to six years. See p. 320

It is very apparent that the disease does penetrate much deeper when potatoes mature under drouth conditions, than when the growing season is prolonged. This is probably due to the much higher temperature of the ground, under which condition the disease likewise makes greater headway on potatoes in storage. It is quite probable that the somewhat droughty period in the latter part of 1908 gave us a higher percentage of seed infection, together with a deeper infection than that of an average season. We may expect this to be the case again from the early matured potatoes of 1910, which failed to catch the early fall rains. Inspection of the seed is certainly advisable.

TABLE II

MEAN AVERAGE TEMPERATURE AND RAINFALL AT WOOSTER FOR THE GROWING SEASONS OF 1908, 1909 AND 1910

Month	1908		1909		1910	
	Mean Temp	Rainfall	Mean Temp	Rainfall	Mean Temp	Rainfall
June.......	68.1	3.17	69.3	6.44	64.3	2.57
July.........	72.4	3.44	69.6	4.05	72.6	1.12
August......	69.0	3.17	70.4	5.21	70.9	.95
September...	66.4	.73	62.2	1.73	65.3	2.59

EARLY VERSUS LATE PLANTING

Much difference of opinion prevails in the potato districts as to the time of planting to obtain the greatest yields. Some prefer to plant medium early, others to plant late, in hopes of striking the fall rains. The writer cares to discuss only the possibility of obtaining a somewhat better seed stock from properly matured late grown potatoes, than from the average or early matured crop. In Bulletin 218 of this Station, Mr. Gourley reports some experiments conducted in 1909 by the Department of Horticulture upon the value of "Late Grown versus Common Potato Seed," in which the yield from the former was 33.7 percent greater than the latter. As far as the Fusarium disease may be related to this, it is quite evident that potatoes maturing under the cool conditions of fall weather will not be as deeply infected as will those tubers maturing under the higher temperatures of late summer. Also the later matured tubers will go into storage in better condition than will the early matured.

STORAGE CONDITIONS FOR SEED PURPOSE

Too much emphasis cannot be placed upon the value of proper storage. Not alone should this emphasis be placed because proper storage controls the Fusarium of dry-rot and other diseases, but because the vitality of the seed is such an important factor in potato

production that it should never be overlooked. There is, in the opinion of the writer, no other single factor so important to the potato industry. In this connection attention is called again to Bulletin 218 of this Station in which Mr. Ballou points out the advantages and disadvantages of each particular kind of storage. The reader is referred to this bulletin. From the observations of the writer, it is obvious that pit storage gives excellent results when properly carried out. It is available to all who have not other proper storage facilities. Mr. Ballou has carefully described the outdoor pit method of storage in the above mentioned bulletin. The writer can do no better than to quote him: "Potatoes may also be buried in out-door pits and kept in fine condition until planting time. A well drained location should be chosen for the pit—one from which the surface water will readily run away. The tubers are piled in conical, pyramidal or long, sharp-ridged heaps, and covered over with six or eight inches of clean straw. Over the straw is covered about six inches of soil. Straw is also spread on the ground in a circle a little distance back from the base of the pit; this is to prevent the ground thus covered from freezing, so that more soil may be readily available when desired. As soon as the first covering of the soil over the pit has become solidly frozen a second covering of straw is added, and over the straw another six inches of soil. The second stratum of soil is then allowed to freeze solid, after which a layer of bundles of corn stover or a heavy covering of straw is placed around or over the pit, to shade and maintain the low degree of temperature prevailing within. Potatoes wintered in this way come out clean, plump, fresh and unsprouted at planting time."

Storage temperatures, when kept below 42 degrees Fahrenheit, will bring potatoes through in excellent condition, and at the same time prevent the Fusarium infection from making much progress.

THE LENGTH OF ROTATIONS

There is much evidence to indicate that many growers are practicing potato rotations of too short a duration. Most of such growers have attempted to maintain a three-year rotation of wheat, clover, potatoes.

The potato and dairy section of the State is well adapted to this practice. However, this disease factor has been giving trouble. It is quite common to find growers who, upon raising a profitable crop of potatoes on an especially well fitted area will run the risk of taking a second crop the next season from the same land. This is certainly poor practice as far as the disease factors are concerned.

PLATE VIII

Showing how differently the disease works on tubers of the same variety. In the tubers at the ft the disease begins its work as a dry rot, while in those at the right the fungus follows the vessels. ıbers, infested as are those on the left, may have the disease cut away. which, when followed by ed treatment (formaldehyde method, see p 332), would give seed free from disease. However, this ould not be possible with the tubers on the right, as they carry the disease in all parts.

Variety, President Roosevelt from L. P. Scott, Kinsman, Ohio.

Scab, rosette, black-leg, the bacterial blight, and the Fusarium wilt may all carry over in the soil, and such successive planting of potatoes on the same area insures more sickness in the seed with each successive crop. Where sufficient care is not given the seed to eliminate the Fusarium fungus, the three year rotation is certainly too short. It will be far more advisable to practice a four-year, or even a five-year rotation, if crops suitable for maintaining fertility and profit can be used. The three-year rotation, wheat-clover-potatoes, at the Station has, during the past two seasons, sustained such heavy losses from the Fusarium blight as to cause those having the management to seriously contemplate dropping the potatoes from the rotation for five years.

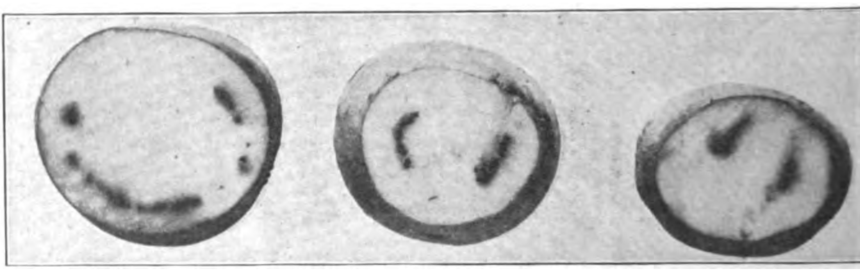


Fig. 1

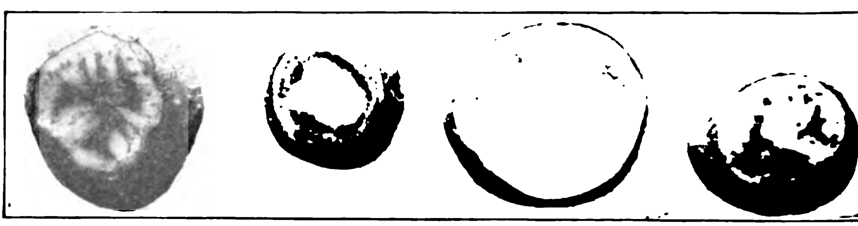


Fig. 2

PLATE IX

The variety in Fig. 1 is President Roosevelt from Portage county. When the disease penetrates deeply into the tubers of this variety, it seems to be confined closely to the ring which contains the water and food conducting vessels (see tuber at left in Fig 1.) The variety in Fig. 2 is Early Ohio from Athens county. The disease in this variety is more or less peppered throughout the tuber.

CARE OF REFUSE AND INFECTED MATERIAL

Emphasis need hardly be placed upon the fact that partially rotted tubers and refuse from storage ought not to be thrown on the manure pile, as this will be a most certain and rapid method of infecting the fields. The better way to dispose of such material is to place it in a pit or on a dump pile from which no distribution will take place.

FIELD EXPERIMENTS IN ITS CONTROL

EFFECTS OF THE DISEASE ON THE STAND

Preliminary experiments in the greenhouse, in which the cted parts of the potatoes (stem ends) were cut away, following ch seed treatment was given, indicated that it was possible to lightly infected seed in this manner after treatment without any ger of the seed carrying the disease. Believing this method ld be made of practical value, a number of field experiments e outlined. Nine different varieties, varying greatly in the :ent and depth of infection with the Fusarium disease, were l in these experiments. The varieties differed greatly as to r seed value on account of storage conditions. In Table III is n a summary of the condition of the seed used.

TABLE III

HOWING THE VARIETIES, SOURCE, CONDITION AND FUSARIUM INFECTION OF THE POTATOES USED IN FIELD EXPERIMENTS IN 1910

'ariety	Source	Condition for Seed	Percent Infected with Fus.	Depth of Fusarium Infection
ion Dollar	Portage Co.	Very poor, cellar storage, much dry-rot.	70 to 90 (?)	⅛ to one inch.
Coin	Seneca Co.	Fair, cellar storage.	14	⅛ inch.
'alters	Seneca Co.	Fair, cellar storage.	10	⅛ inch.
'alters	Trumbull County	Poor, cellar storage, wire-worm eaten.	40 to 60 (?)	⅛ to ½ in. or more.
. Roosevelt	Trumbull County	Good, unsprouted, plump, very deeply infected.	52 to 95	52 % deeper than ¼ inch.
'Ohio	Athens Co.	Fair, sprouted, shrunken.	76	Shallow
Cobbler	Athens Co.	Fair, sprouted, shrunken.	80	Shallow
onals	Erie Co.	Good, plump, little sprouted.	11	⅛ inch or more.
.ll	Erie Co.	Good, plump, little sprouted.	10	⅛ inch or more.

Several of the more deeply infected of these varieties were l a number of times in small plot work to determine the influ- : of depth of infection upon yield and upon stand. The variety s. Roosevelt, illustrated in Plate X, was used in one of these s as follows: In a comparison of seed in which the infection was away with seed in which the infection penetrated from one- th to one inch, and also with seed in which the infection pene- ed more than one inch, a considerable difference was to be :d both in the stand and the yield. A row of 20 hills with each l of seed was planted. Two half tubers were placed in each —all the seed was treated with formaldehyde. Each of the s was sprayed with Bordeaux mixture. The summary is given 'able IV.

In the above experiments we have only the one varying factor, the amount or depth of Fusarium infection; it is quite plain : seed, badly infected internally though apparently very sound plump, will lower the yield considerably.

TABLE IV

SHOWING EFFECT OF DEPTH OF INFECTION UPON STAND AND YIELD
VARIETY PRESIDENT ROOSEVELT

Row	Treatment	Effect on stand	Yield based on % of row 1
1	Infection cut away, seed treated.	Stand very good, plants up very even.	100.
2	Infected ½ to 1 inch deep, seed treated.	Stand very good, slightly uneven.	86.6
3	Infected one inch or more, seed treated	Stand fair, quite uneven.	71.2

Another experiment showed plainly the effect of diseased material in retarding the growth and in producing an uneven stand. Two rows of 18 hills each were planted with treated seed from which the infection had been removed. Three different varieties were used, viz., Nationals, Irish Cobbler and Early Ohio; six hills (two half tubers to the hill) were planted with each variety in each row, care being taken to use one-half of each tuber in each of the rows. One of the rows was infected by using a thin slice of dry-rotted tubers, which was placed directly beside the seed. This manner of infection proved very severe. (See Plate IV, lower illustration; the infected row is at the right.) The plants were very much slower in coming in the infected row, and the stand was very irregular; the yield was reduced 46.6 percent below the non-infected row. All the varieties suffered about equally from the Fusarium infection.

RESULTS FROM FIELD EXPERIMENTS

One requisite in conducting experiments in the field was to secure areas for plot work which were not already diseased. In this we were quite successful. The field on which the experiments were conducted at Wooster had not grown potatoes for at least 17 years, and quite probably previous to that time had never had potatoes on it. The field at Mantua was a timothy sod, and had not raised potatoes for at least 6 or 7 years. At Kinsman the field had been used in potatoes three years previous to 1910. According to the knowledge of the owner the field at Tiffin had never been in potatoes. In the treatment of the potatoes at Kinsman an error was made in letting the potatoes stand six hours in the formaldehyde solution, instead of two; as a result of this oversight the stand in Plot 2 was reduced nearly 50 percent. On account of this error no comparison could be made in the yields. The overtreated plot, however, gave some valuable data in regard to the amount of Fusarium infected vines it contained as compared with the other plots. The writer is indebted to Mr. Arzberger, Assistant Botanist, for

ting the data at harvest time on the plots at Kinsman. He noted it the over-treated plot (See Table V, p. 327 work at Kinsman, ot 2) showed only 4 to 5 percent of the vines infected with the Fu-rium blight; whereas, the other plots showed from 20 to 70 percent.

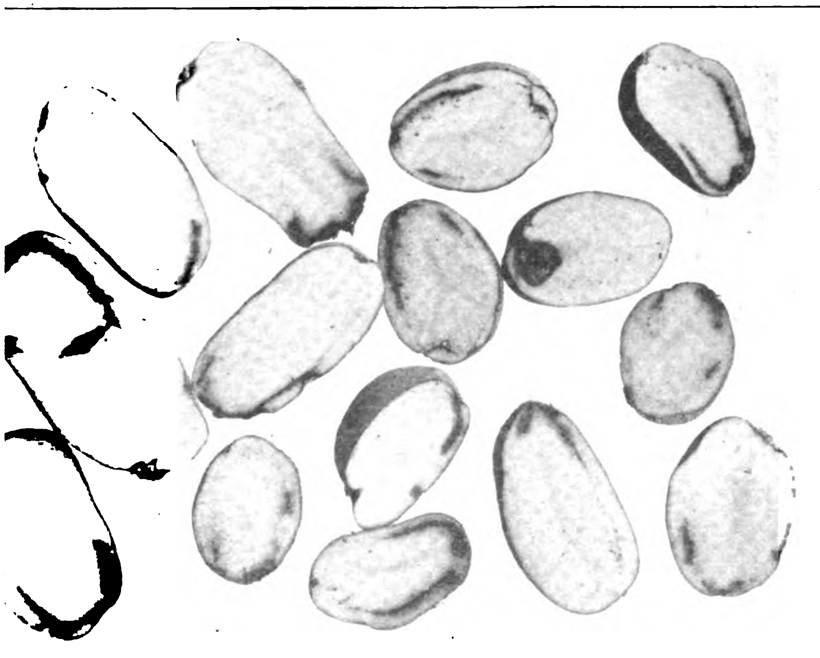
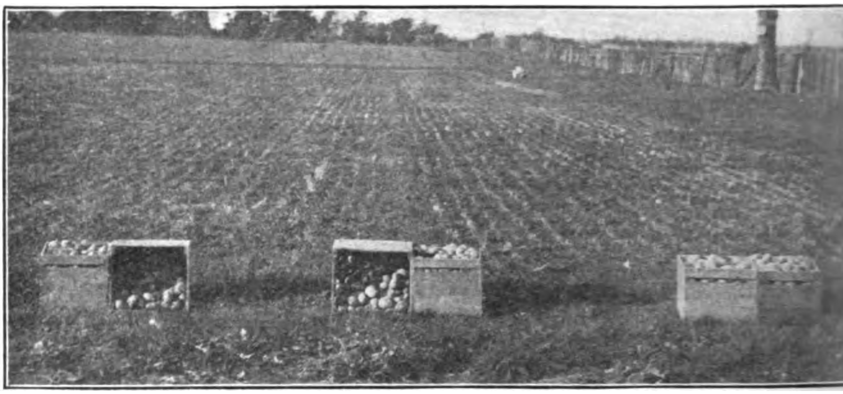


PLATE X

howing type of seed used in experiments at Wooster, O., during the season of 1910. This seed infected one inch or more in depth from the stem end; the half tubers were used in planting just otographed (see p 327 for data on yields and also Plate XI and description of same.) In regard to the ield—Mr. L. P. Scott says: "While our potatoes in 1909 were of good size and appearance the was small, only about 70 bushels per acre of two varieties, the Roosevelt and Prince Henry."

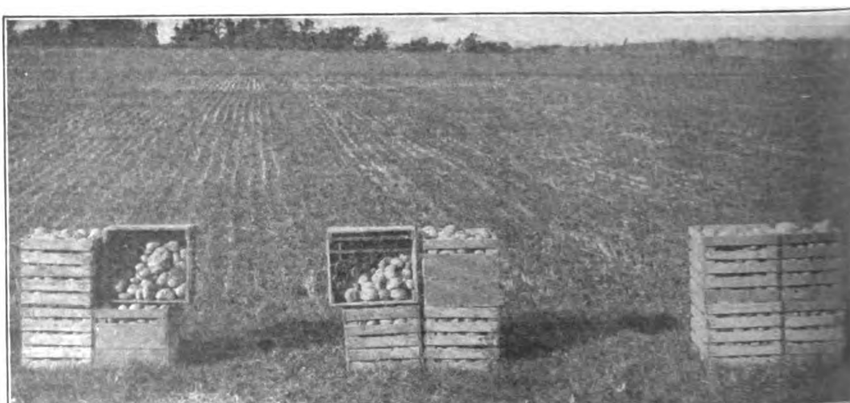
In the work at Wooster the variety Pres. Roosevelt afforded an :llent opportunity to study the Fusarium disease, as the seed deeply infected, though very plump. (See Plate X.) The ace treatment of the infected seed left only the one factor at x in the plot, viz., the internal Fusarium infection. Hence, in 3 of the variety Pres. Roosevelt (Table V) the Fusarium symp-s showed up distinctly on 71.1 percent of the vines, six weeks re maturity, while the non-infected plot showed only 4.7 percent e vines infected. The amount of Fusarium infection which the used in these experiments was carrying is given in Table III, :3. In Table V is given a summary of the yields from all the

plots in the field work, together with the gains or losses in percent resulting from clipping away the infected parts of the tubers and then treating with formaldehyde. In this summary (Table V) the varieties are arranged according to the amount of internal Fusarium infection they were carrying, the heaviest infected being placed first.



Fusarium infected seed Treated—yield 80 lbs. **Fusarium infected seed Not treated—yield 84 lbs.** **Infection cut away Treated—yield 119.5 lbs.**

Fig. 1



Fusarium infected seed Treated—yield 220 lbs. Fusarium infected seed Not treated—Yield 199 lbs. Infection cut away Treated—Yield 240 lbs.

Fig. 2

PLATE XI

Showing yields from the different treatments given potatoes in the control of Fusarium infected seed. The variety President Roosevelt shown in Fig. 1 was grown from seed infected as shown in Plate. X. In the plot planted with seed in which the disease was clipped away and the seed then treated with a solution of formaldehyde the yield was increased 42.2 percent.

In the variety Noxalls, as shown in Fig. 2 the plot planted with seed in which the infected parts were cut away previous to treatment the yield was increased 20.6 percent over the untreated plot. This latter variety was not so badly infected as the variety President Roosevelt. Seed potatoes should be inspected, the diseased parts cut away and the seed treated (see p. 332.) The plots at the left were planted with treated seed in which the diseased parts were not cut away. In yield they were about e qual to the untreated plots.

The increased yields brought about by cutting away the infection and treating the seed varied just about in proportion to the amount and severity of the Fusarium infection. Four of the experiments gave the following gains, 42.26 percent, 20.61 percent, 15.14 percent, and 2.95 percent respectively. One experiment gave a loss of 5.19 percent. Considerable irregularity is to be noted in several of the experiments, as is exhibited in the summary, Table V.

TABLE V

SUMMARY OF FIELD EXPERIMENTS IN 1910 SHOWING YIELDS AND RESULTS OF TREATMENTS

Plot No.	Treatment	Size of Plot	Yield in lbs Mark-etable	Small	Average Bu. per Acre	Percent of Increase by Treatment
	Variety, President Roosevelt, Wooster, Wayne county					
		Acre				
1	Infection cut away, treated.	1-25	119.5	Not	49.99	+42.26
2	Infection not cut away, not treated.	1-25	84.	taken	35.14	
3	Infection not cut away, treated	1-25	80.	out	33.46	
	Variety, Million Dollar. Mantua. Portage county					
1	Infection not cut away, treated.	1-10	471.	65.	80.93	
2	Infection cut away, treated.	1-10	575.	56.	105.16	+15.14
3	Infection notcut away, not treated.	1-10	490.	58.	91.33	
	Variety, Sir Walter Raleigh, Kinsman, Trumbull county					
1	Infection not cut away, not treated.	1-12	320.	11.	66.12	
2	Infection cut away, seed treated.*	1-12	181.5	3.	36.84	(?)*
3	Infection cut away, seed not treated.	1-12	288.	22.	61.92	
4	Infection cut away, seed treated.	1-12	269.	9.	55.56	
	Variety, Noxals, Wooster, Wayne county.					
1	Infection cut away, treated.	1-25	240.	Not	100.40	+20.61
2	Infection not cut away. not treated.	1-25	199.	taken	83.24	
3	Infection not cut away, treated.	1-25	220.	out	90.20	
	Variety, Gold Coin, Tiffin, Seneca county					
1	Infection tot cut away, not treated.	1-30	62.5	63.5	63.00	
2	Infection cut away, not treated.	1-30	78.	66.5	72 24	
3	Infection cut away, treated.	1-30	71.	48.5	59.73	—5.19
4	Infection not cut away, treated.	1-30	77.	49.	63.00	
	Variety, Sir Walter Raleigh, Tiffin, Seneca county					
5	Infection not cut away, not treated.	1-30	176.5	45.	110.73	
6	Infection cut away, treated.	1-30	164.	64.	114.00	+2.95

*Error in treatment—Seed stood in solution 6 hours instead of 2. Stand injured about 50 percent.

Treatment alone, without cutting away the infection, as a rule gave no better results than the untreated, showing that the chief factor in reducing the yield was the Fusarium infection which was internal in the seed, and the treatment did not reach it.

In examining the tubers from each of the plots, it was quite evident that, where infected and untreated seed was used, the amount of internal infection was much higher. In the variety President Roosevelt, in Plot 2, 76 percent of the tubers showed internal infection, and nearly one percent was partially or completely dry-rotted in the field. In this same variety, Plot 1, planted with seed from which the infection was cut away, and the seed then treated, gave less than one percent carrying internal infection. The dry rotting at the stem end was not noted in the other varieties, except a very slight amount in the Sir Walter Raleighs at Kinsman.

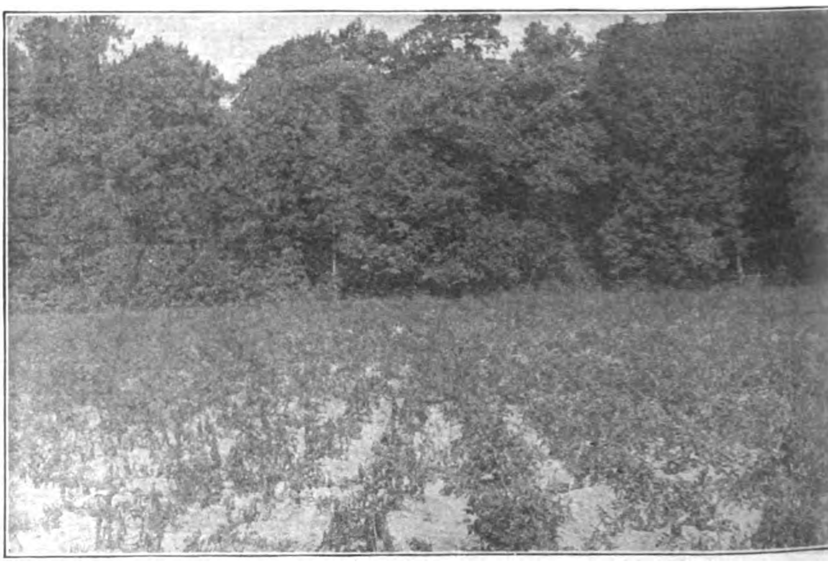


PLATE XII

Showing the results of spraying at Mantua in 1909, when no early or late blight was active. The only active factor in reducing the yields was the Fusarium blight. The heavier sprayed plots, viz. those sprayed with the 6-6-50 Bordeaux, stood up over two weeks longer than the unsprayed. The plot at the right (4 rows) sprayed with the 6-6-50 Bordeaux averaged 22.8 bushels more per acre than the unsprayed beside it (see Table VI, p 329).

EFFECTS OF SPRAYS ON FOLIAGE

The Fusarium disease being a soil trouble, and infecting the plant through the root system, it was not expected that spraying the foliage would yield any results. During the season of 1909 the Department of Botany conducted potato spraying experiments in coöperation with Mr. M. E. Yonker at Mantua, Portage County. Fortunately, for the study of this disease, the only active factor at work in 1909 in reducing the yields on the area plotted for spraying was the work of the Fusarium blight, which was very prevalent.

Evidently the soil was somewhat infested. The symptoms of the disease were conspicuous throughout most of his fields. In some spots the disease was furthered by the activity of the white grubs. However, the grubs interfered little or none with the area on which the spraying tests were carried out.

For some reason the sprayed plots, especially the heavier sprayed plots, viz., those sprayed with 6-6-50 Bordeaux, showed much less premature dying than did the unsprayed plots. (See Plate XII.) It is difficult to explain this. The difference was not due to the activity of early or late blight, nor to flea beetles, though some few were present; the white grubs were not a factor. The growth in all sprayed plots continued from one to three weeks longer than that in the unsprayed. Many of the plants in the heavier sprayed plots continued their growth fully three weeks longer than did those in the unsprayed plots. Whether the action of the spray is that of a stimulant to the plants or whether it partly controls the Fusarium fungus cannot be said. The fact, however, stands out that the growth in the sprayed plots continued from one to three weeks longer than in the unsprayed, and the yield was thereby increased on an average of 11.36 bushels per acre. Further work is required upon these points.

TABLE VI

SHOWING YIELDS OF POTATOES IN THE 1909 SPRAYING TEST AT M. E. YONKER'S, FARM MANTUA, OHIO

Plot No	How Sprayed	Variety	No. of row in plot	Rows dug & weighed	Yield in lbs.		Average Yield in bus. on Acre Basis	
					Mrktbl	Small	Unsprayed	Sprayed
1	Unsprayed	Million Dollar	8	4	969.	51	153.0	
2	4-4-50*	" "	8	4	1210.	50		189.0
3	6-6-50	" "	8	4	1221.	45		189.9
4	Unsprayed	4 rows Mil. D. 1 row Gold Coin 3 rows Sir Wal.	8	2 M D. 2 S.W.R.	1137.	69	180.9	....
5	2-4-6-50	Sir Walter Ral.	4	2	598.	55		195.9
6	4-4-50	" " "	4	2	535.	31		169 8
7	Unsprayed	" " "	4	2	542.	40	174.6	
8	6-6-50	" " "	4	2	605.	53		197 4
9	2-4-6-50	" " "	4	2	564.	45		182.7
10	Unsprayed	" " "	4	2	507.5	38	163.6	
11	4-4-50	" " "	4	2	520.5	25		163.6
12	6-6-50	" " "	4	2	538.	32		171.0
13	Unsprayed	" " "	4	2	570.	43	183.9	
14	2-4-6-50	" " "	4	2	531.	40		171.3
15	4-4-50	" " "	4	2	582.	40		186.6
16	Unsprayed		4	2	516.	38	166.2	

Average yield per acre unsprayed..170.36
Average yield per acre sprayed..181.72
Average gain per acre from spraying..11.36

*These spray mixtures are given in the Spray Calendar, Bull. 199, of this Station.

In Table VI is given the data for the spraying work at Mantua, Portage Co. The only point of interest in these 1909 spraying results at Mantua is the influence of the sprays in slightly retarding the work of the Fusarium blight.

The writer is satisfied that spraying heavily four times during the season does somewhat retard the activity of the Fusarium fungus. Just how the results are brought about cannot be satisfactorily explained.

RECOMMENDATIONS FOR THE CONTROL OF THE DISEASE

CAREFULLY INSPECT THE SEED

The first requisite is to know the disease. The later stages of the disease, viz., dry-rot, is easily recognized. The potato grower should become so familiar with the internal symptoms as to recognize the disease at a glance. By carefully cutting knife sections across the stem end of the tubers the infected potatoes will show up similarly to those in Plates II, VIII, IX and X. Determination of the depth and percentage of infection should be made at the time of digging. Should the grower fail to make inspection previous to placing the crop into storage and later finds a large percent infected, it will be wise to give the storage conditions particular attention.

WHAT TO DO WITH SICK SEED

It will certainly not be advisable to place badly infected seed in cellar storage. A much safer plan would be to select out the amount required for table use and sell the remainder for early consumption. If the crop is so little infected that the diseased parts of the tubers may be cut away, then it may be advisable to select out the amount necessary for seed and place this in a more favorable storage; if no better method is available, the out-door pit storage, when properly carried out (see p. 320), will answer very well.

It is a pretty sure indication that the crop has ripened prematurely, when the potatoes are carrying a high percent of infection, though the fungus may not penetrate very deep; it is also true that such seed will not have the vitality or keeping qualities of seed that has properly matured.

Potatoes which are so badly marked internally as to be unfit for table use may be fed to the hogs, or other stock when properly handled. The fungus will in no way injure the animals. Manure produced in feeding badly infected raw tubers should be spread on permanent pastures or applied so as not to carry the disease to areas which will be used for potatoes.

MAINTAIN A SEED PLOT

Disease has become such a factor in all farm crops that it is high time that more attention should be given to the production of a better grade of seed. This can be done only by giving more attention to the area and seed which go to produce the crop for the

ollowing season's use. To this end a seed plot should be selected :ach year on an area that the grower is well satisfied carries no otato troubles and large enough to supply in an average season ully double the amount of seed required. This will give an opporunity to do hill selection at the time of digging, thus keeping the eed up to a high yielding basis and of uniform quality.

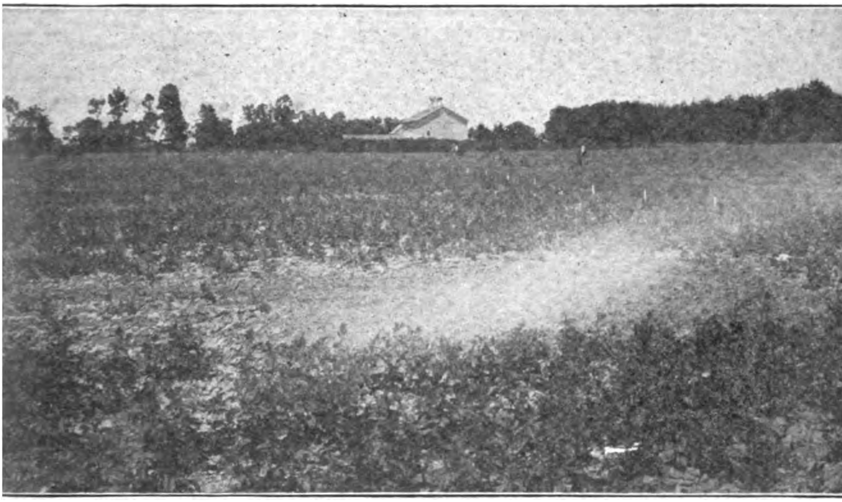


PLATE XIII

Showing a small area (2x3 rods) of soil so infested with the Fusarium disease of potatoes that no ants matured whatever. Just how long this disease may continue in soil once infected has not been termined. In soils rich in humus the evidence points to the disease continuing for several years ithout the intervention of the potato crop.

The field from which this photograph was taken was so sick with the Fusarium blight, aided by ıb worms, that less than 39 percent of a fourteen-year average crop was realized. From wheatver-potato rotation, S. E. farm, Wooster, Ohio, 1909.

Indifference to seed is probably costing the grower more than ıy other factor in potato growing. This seed plot, to begin with, ıould be planted with the best seed obtainable, free from internal seases, and treated externally with formaldehyde just previous to anting. Care should be taken throughout the season that implements used on sick fields are properly cleaned before being used on e seed plot. Spraying should be practiced to prevent foliage oubles. Late blight, should it strike the field in the absence of oper spraying, will infect internally much of the seed and cause storage rot.

The seed plot should be dug by hand or plowed up in order that e product from each hill may be kept together to permit of hill lection. But little time need be consumed in making this

selection, as one picker can gather 30 to 40 percent of the hills for seed purposes while the other gathers the remainder. The wagon box may be divided to accommodate the two divisions. Immediately upon drying the potatoes selected for seed should be placed in the best available storage.

TREATMENT PREVIOUS TO PLANTING

Previous to seed treatment, the tubers should be inspected and if the seed is carrying a shallow infection, this should be cut away. This can be done without injuring in the least the potatoes for seed purposes.

There are two satisfactory methods of treating seed potatoes. The older method is carried out by placing the seed in a solution made by using one pound of formaldehyde (40 percent grade) in 30 gallons of water. The seed remains in this solution one ond one-half to two hours. It is then removed and allowed to dry. A longer treatment than two hours will injure the seed. A treatment of one-half hour is sufficient when the seed is not carrying scab or the fungus of the rosette disease.

The easier treatment, also the most rapid, is the formaldehyde gas method. It requires a room that may be made reasonably tight by blocking cracks and knot holes. This method is given in the Ohio Station Bulletins 199 and 214, from which the writer will quote the formula and operations.

FORMALDEHYDE GAS

Commercial 40 percent formaldehyde	3 pounds
Potassium permanganate	23 ounces

Sufficient for 1000 cu. ft. of space occupied by crates or trays.

"Enclose open tiers or piles of slat crates filled with dry onions, potatoes, etc., in tight room or oiled tent or canvas buried in the earth about the base. Generate the formaldehyde gas in a flat bottomed dish or pan of adequate capacity by placing one of the materials, as the liquid formaldehyde, in the pan, and adding the other the last thing before retiring. Then close tight and allow to remain closed 24 to 48 hours.

"Proportionate or multiple unit amounts may be taken for smaller or larger enclosed spaces. Applicable to fumigation of seed potatoes for scab, sweet potatoes for rot troubles and to newly gathered, dry onions before storing for winter."

WHAT TO DO WITH SICK FIELDS

The grower should become familiar with the field symptoms as herein described. The behavior of the crop during the growing season should be carefully noted.

Where soils have become badly infested with the Fusarium fungus, it is certainly advisable to drop the growing of potatoes from the sick areas for at least five or six years. (See p. 320.) In the meantime, grain or grass crops will undoubtedly be the most favorable means to work out the disease. Smith and Swingle[5] carried out a series of experiments to learn what effect certain fertilizers would have upon the disease; they found no beneficial results so far as controlling the disease was concerned. There is little to be expected in the way of a soil remedy.

PLATE XIV

Illustration showing the "internal blotch" of potato, a disease which may be confused with the internal markings of the Fusarium infection. The cause of this newly observed trouble is not known. It is characterized by irregular rusty blotches throughout the flesh and may be due to excessive variations in the growing season, such as long droughts, following which favorable weather brings about an exceedingly rapid tuber formation. One sample showed fully 15 to 20 percent of the tubers having the disease.

POTATO TROUBLES IN OHIO WITH WHICH THE FUSARIUM DISEASE MAY BE CONFUSED

INTERNAL BLOTCH

This internal trouble of the potato, with which the writer has done microscopic and culture work, may be confused by the layman with the internal markings of tubers by the Fusarium fungus. It is

characterized by rusty blotches, irregularly distributed throughout the flesh. (See Plate XIV.) No external symptoms are in evidence; the trouble is to be observed only by cutting into the tuber. During the past two seasons this trouble has been met with occasionally while making examinations for the Fusarium infection. The cause of the disease is not known. Microscopic examinations and artificial culture work failed to reveal any organism. For the present it must be classed among the physiological troubles, and is presumably due to irregularities in the growing season. This year (1910), in late potatoes which had made a rapid growth following the extreme drouth of the summer, one of the buyers reported that in one lot between 15 and 20 percent were infected with this disease.

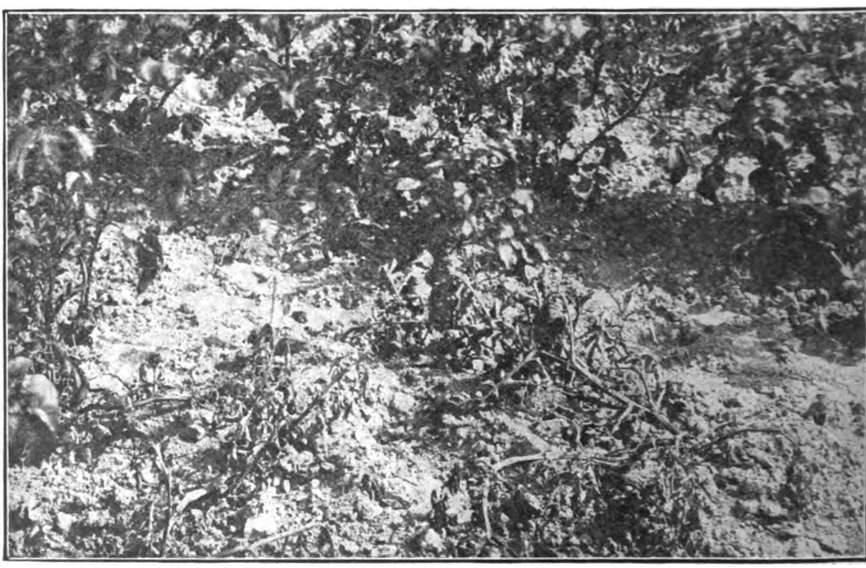


PLATE XV

Showing the work of what is probably the bacterial trouble of the potato, known as "black-leg," disease which by the layman may easily be confused with the Fusarium blight. It is characterized by a much more rapid wilt than that of the Fusarium disease. and generally the root of the attacked plant just below the surface of the ground becomes so badly rotted (and blackened) that the plant usually falls. The collapse from this disease takes place in such a short time that the plant fails to take on the yellowing symptoms so indicative of the Fusarium blight.

A. S. Horne[11] reports having worked with the disease in England, which he designates, "internal disease and sprain." His microscopic examinations did not reveal a specific organism. He carried out some experiments to learn whether infested seed would

[11] Horne, A. S. The Journal of Agr. Science, III Part 3: 322-332; 1910.

transmit the disease. His results could hardly be considered positive. It seems quite probable that the trouble is partly inherited by certain strains, and closely associated with irregularities in the growing season.

BLACK LEG

The symptoms of this disease in the field may be misunderstood for that of the Fusarium blight. This is a bacterial disease which rots the base of the stem and root causing a blackened lesion, from which the popular name is derived. The rapid decay of the shank causes a wilt. The disease progresses much more rapidly than does the Fusarium blight, and it is not accompanied with the marked yellowing symptoms which characterizes the latter. What appears to have been this trouble was met with at Kinsman, Trumbull county, the past season (See Plate XV). Nearly full grown plants would rapidly wilt and the stem below the ground would rot so badly as to allow the plant to fall. (See Ohio Station Bulletin 214.)

ACKNOWLEDGEMENTS

The writer desires to thank Prof. A. D. Selby, Chief of the Department of Botany, for his directions and kindly assistance in furthering the work. To Mr. Joseph H. Gourley for the valuable observations made upon field conditions in 1909; to Mr. E. G. Arzberger, Assistant Botanist, for gathering the harvest data at Kinsman, for noting the field conditions at Mantua, and assisting otherwise.

The Department is indebted to the cooperators Messrs. Dan Egbert, Mark E. Yonker, and F. L. Allen for carrying out demonstration work in the field. A number of others have contributed largely in furnishing infected seed, sick plants, and field and storage observations.

To Mr. Wm. P. Beeching, the photographer, is due credit for finishing all the prints, and taking Plates VIII and XIV.

SUMMARY

1. The dry-rot fungus (*Fusarium oxysporum* Schlecht) of potato proves to be a field trouble common in Ohio, which causes a blight and wilt of the crop.

2. It produces a sick soil condition in potato districts.

3. The field symptoms are characterized by a cessation of growth, a yellowing of the foliage, with an upward and inward rolling of the upper leaves, accompanied by wilt during the heat of the day.

4. The sick soil conditions may reduce the yield to 50 percent or more of an average crop.

5. The causal fungus is carried within the tubers.

6. The internal infection is characterized by brown or blackened areas usually in the vascular ring; occasionally it specks the flesh in other areas.

7. Internally infected tubers are the chief means of distributing the disease.

8. The presence of the disease in the tubers may be made known by cutting knife sections from the stem end.

9. The infection may be removed from slightly infected seed by clipping away the stem end and following by external treatment with formaldehyde.

10. No attempt should be made to use deeply infected seed as the infection cannot be cut away.

11. Slightly infected seed will not materially reduce the yield the first season. It is a means, however, of infecting the soil, which may later result in sick fields.

12. Spraying will not control the disease.

13. Proper storage prevents the progress of the disease as a dry-rot.

14. Careful inspection of the seed should be made before placing it in storage. Cellar storage under dwellings should be avoided when seed is infected. Proper pit storage will give better results.

15. A seed plot on non-infected soil planted with carefully selected healthy seed will offer a means of getting a sound seed supply.

16. Sick fields should not be planted in potatoes again for at least five or six years, and even longer time may be required to work the parasitic fungus from the soil. Grass and grain crop will undoubtedly eliminate the fungus from the soil quicker than will manuring and cultivated crops.

17. Longer than a three-year potato rotation should be practiced.

18. Storage litter and sick seed should not be allowed to reach the manure pile, as this will be a sure method of distributing the disease and infecting the fields.

19. The disease demands further study. The Department of Botany invites cooperation with potato growers. Examination of seed potatoes and plants will be made and the results reported. This Department, in cooperation with the Bureau of Plant Industry of the U. S. Department of Agriculture, has the franking privilege on diseased plant material; the franks will be sent to those having diseased material to be forwarded.

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FOR 1910-1911

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OHIO

Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., JULY, 1911.

BULLETIN 230

The Bulletins of this Station are sent free to all residents of the State who request them. When a change of address is desired, both the old and the new address should be given. All correspondence should be addressed to EXPERIMENT STATION, Wooster, Ohio.

Thirtieth Annual Report

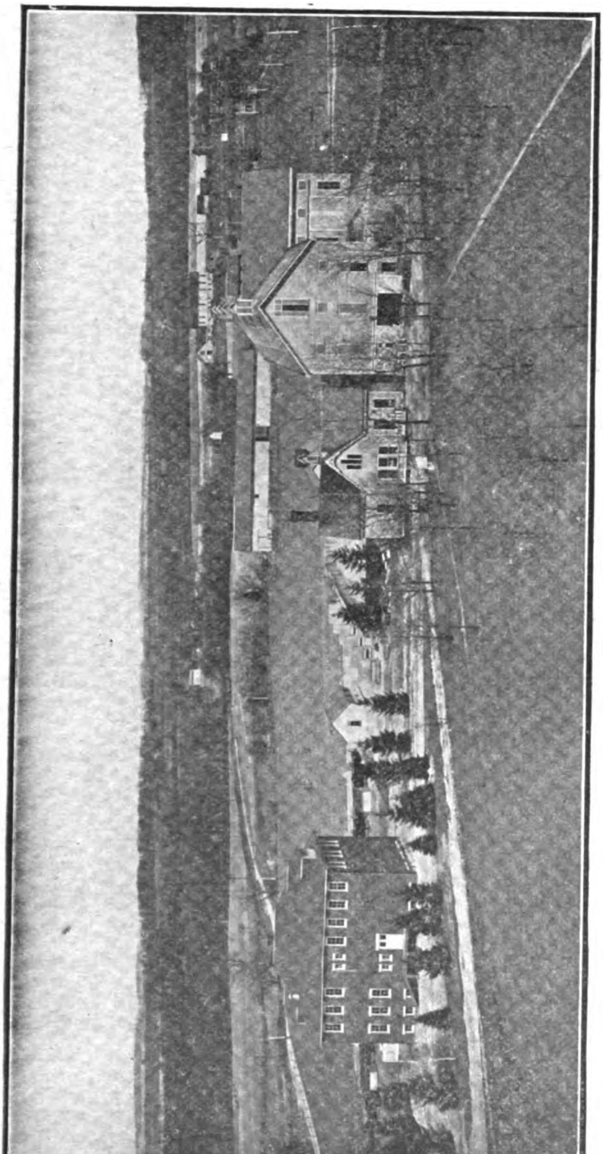
OF THE

Ohio Agricultural Experiment Station

For the Year ending June 30, 1911

Published by order of the State Legislature

WOOSTER, OHIO
EXPERIMENT STATION PRESS
1911



OHIO AGRICULTURAL EXPERIMENT STATION

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J. D. GUTHERY, *Treasurer* .... Marion
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FRANK B. BLOOD .... Conneaut

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H. M. WACHTER, *Supt. Test-farm*, Germantown

REPORT OF THE BOARD OF CONTROL

To His Excellency, JUDSON HARMON, *Governor of Ohio:*

SIR: I have the honor of submitting herewith the thirtieth annual report of the Ohio Agricultural Experiment Station, for the year ended June 30, 1911.

STATE APPROPRIATIONS

The following sums have been appropriated by the last General Assembly for the support of the Station during the fiscal years 1911 and 1912:

	1911	1912
For Department of Administration	$ 30,000	$ 35,000
" " " Agronomy	15,685	18.000
" " " Animal Husbandry	20,000	20,000
" " " Botany	7,000	10,000
" " " Cooperation	25,000	30,000
" " " Entomology	5,600	8,000
" " " Forestry	7,400	12,000
" " " Soils	17,000	20,000
" " " Chemistry	3,600	5,000
" " " Horticulture	14,000	17,000
" " " Nutrition	7,000	8,000
" " " Dairying	7,200	10,000
" Furniture and carpets	750	500
" Addition to main building	20,000	
" Addition to power house and equipment	10,000	
" Construction of sheds	3,500	
" Purchase of land at Germantown	6,355	
Total	$200,090	$195,300

These appropriations provide for the addition to the administration building and for the purchase of the Germantown Test Farm, as requested in our last report, and for a much needed extension and readjustment of the heating system.

COUNTY EXPERIMENT FARMS

Several counties voted in November upon the question of establishing county experiment farms under the law enacted in 1910, and the measure was carried in Paulding, Miami, Belmont and Clermont counties. Upon invitation of the Boards of County Commissioners

the Board of Control visited Paulding, Belmont and Miami counties in March and April, and with their approval the Commissioners of Miami county have purchased a farm of about 123 acres, lying two miles northwest of Troy, and those of Paulding county have purchased a tract of 92 acres, a mile and a half south of Paulding. A location selected by the Commissioners of Belmont county was approved by the Board of Control, but before the purchase was consummated certain citizens who were dissatisfied with the location instituted injunction proceedings and the matter has not yet been decided.

An invitation was received late in June from the Commissioners of Clerment County to assist in selecting a farm for that county and it is expected that this will be accomplished within a few weeks.

Both the Miami county and Paulding county farms had been leased for the season, but it was found possible to make satisfactory arrangements with the lessees, under which they surrendered their claims to the Experiment Station and took service under it, so that a beginning has been made in preparing these farms for their purpose.

In selecting these farms the effort has been made to secure soils representing as large areas as possible of the counties in which they are located, and it is hoped that the work done on them may prove to be of great value to the agriculture of those counties.

PERSONNEL

The term of office of Mr. John Courtright having expired, Mr. Frank B. Blood of Conneaut, was appointed to succeed him.

At the annual meeting of the Board, held in March, D. L. Sampson was elected President, H. L. Goll, Secretary, and J. D. Guthery, Treasurer.

Respectfully submitted,

H. L. Goll,

Secretary of the Board of Control.

REPORT OF THE BURSAR.

MR. D. L. SAMPSON, *President of the Board of Control:*

DEAR SIR: I respectfully submit herewith the financial report of the Station for the fiscal year ending June 30, 1911.

In statements A, B, C, D and E, respectively, will be found a record of receipts and expenditures from the various funds; statements A and B being statements of account with the appropriations received from the U. S. Treasury and a copy of the report made to the Governor of the State, the U. S. Secretary of Agriculture, and the Secretary of the U. S. Treasury; statement C being a statement of account with the State Treasury, and statement D showing the receipts from farm produce and other sources and the expenditures from that fund.

The four statements, A, B, C, and D, are combined in statement E, which shows the total income and expenditures for the fiscal year.

STATEMENT A

Hatch Fund

THE OHIO AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH THE UNITED STATES APPROPRIATION UNDER THE HATCH ACT FOR 1910-1911.

Dr.

To receipts from the Treasurer of the United States, as per appropriation for the fiscal year ending June 30, 1911, as per act of Congress approved March 2, 1887		$ 15,000.00

Cr.

By expenditures for:—		
Salaries	$ 12,503.31	
Labor	363.70	
Publications	1,414.57	
Postage and stationery	1.43	
Seeds, plants and sundry supplies	10.45	
Traveling expenses	36.90	
Buildings and repairs	669.64	
Total		$ 15,000.00

STATEMENT B

Adams Fund

THE OHIO AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH THE UNITED STATES APPROPRIATION UNDER THE ADAMS ACT FOR 1910-1911

Dr.

To receipts from the Treasurer of the United States, as per appropriation for the fiscal year ending June 30, 1911, as per act of Congress, approved March 16, 1906	$ 15,000.00

Cr.

By expenditures for:—		
Salaries	$ 11,080.95	
Labor	976.08	
Postage and stationery	.93	
Chemical and laboratory supplies	868.99	
Seeds, plants and sundry supplies	33.70	
Library	32.50	
Furniture and fixtures	4.00	
Scientific apparatus and specimens	1,114.73	
Traveling expenses	138.12	
Buildings and repairs	750.00	
Totals		$15,000.00

We, the undersigned, duly appointed Auditors of the Corporation, do hereby certify that we have examined the books and accounts of the Ohio Agricultural Experiment Station for the fiscal year ended June 30, 1911 that we have found the same well kept and classified as above; that the receipts for the year from the Treasurer of the United States are shown to have been $15,000.00 under the act of Congress of March 2, 1887, and $15,000.00 under the act of Congress of March 16, 1906, and the corresponding disbursements $15,000.00 and $15,000.00; for all of which proper vouchers are on file and have been examined and found correct.

And we further certify that the expenditures have been solely for the purposes set forth in the acts of Congress approved March 2, 1887, and March 16, 1906, and in accordance with the terms of said acts, respectively.

Signed:

GEO. E. SCOTT,
F. B. BLOOD,
Auditors.

STATEMENT C

State Appropriations

THE OHIO AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH THE STATE TREASURY

Date of appropriation	Appropriation for:—	Total amount to Station's credit	Total amount expended	Balance in treasury June 30, 1911
1911	Administration	$ 30,000.00	$ 10,415.88	$ 19,584.12
	Furniture and carpets	750.00		750.00
	Agronomy	15,685.00	879.26	14,805.74
	Animal Husbandry	20,000.00	9,641.12	10,358.88
	Botany	7,000.00	498.61	6,501.39
	Cooperative Experiments	25,000.00	5,783.63	19,216.37
	Entomology	5,600.00	468.71	5,131.29
	Forestry	7,400.00	2,889.76	4,510.24
	Soils	17,000.00	3,973.83	13,026.17
	Chemistry	3,600.00	190.66	3,409.34
	Horticulture	14,000.00	3,188.51	10,811.49
	Nutrition	7,000.00	488.65	6,511.35
	Dairy Husbandry	7,200.00	1,948.92	5,251.08
	Purchase of land at Germantown	6,355.00		6,355.00
	Addition to Administration Building complete	20,000.00		20,000.00
	Addition to power house and equipment complete	10,000.00		10,000.00
	Construction of sheds	3,500.00		3,500.00
	Totals for 1911	$200,090.00	$ 40,367.54	$159,722.46
1910	Administration	$ 21,215.19	$ 21,215.19	$
	Furniture and carpets	500.00	499.60	.40
	Agronomy	13,280.66	13,280.66	
	Animal Husbandry	11,029.48	11,029.48	
	Botany	9,188.76	9,188.76	
	Cooperative Experiments	14,307.45	14,307.45	
	Entomology	4,234.86	4,234.86	
	Forestry	7,660.58	7,660.58	
	Soils	7,536.84	7,536.84	
	Chemistry	3,700.00	3,700.00	
	Horticulture	8,301.32	8,301.32	
	Nutrition	3,938.85	3,938.85	
	Dairy Husbandry	8,000.00	8,000.00	
	Completing Nutrition building	17,000.00	17,000.00	
	Purchase of land	4,000.00	4,000.00	
	State's share of assessment for road construction	500.00		500.00
	Extension of Power House	3,000.00	3,000.00	
	Totals for 1910	$137,393.99	$136,893.59	$ 500.40
1909	Furniture and carpets	$ 431.27	$ 431.27	
	Chemistry	725.89	725.89	
	Nutrition	4,736.12	4,736.12	
	Totals for 1909	$ 5,893,28	$ 5,893.28	
	Totals for 1909, 1910, 1911	$343,377.27	$183,154.41	$160,222.86

STATEMENT D

Produce Fund

THE OHIO AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH THE PRODUCE FUND

Dr.

To Receipts

From Department of Administration	$ 1,082.43	
" " " Agronomy	2,527.71	
" " " Animal Husbandry	13,029.71	
" " " Botany	3.58	
" " " Cooperative Experiments	1,115.25	
" " " Chemistry	11.50	
" " " Entomology	616.65	
" " " Forestry	20.40	
" " " Horticulture	4,227.69	
" " " Nutrition	636.38	
" " " Soils	669.29	
" " " Dairy Husbandry	1,831.59	
Total receipts for the year		$25,772.18
To balance brought forward July 1, 1910		2,209.58
Total		$27,981.76

Cr.

By Expenditures

For Salaries	$ 3,906.74	
" Labor	2,992.59	
" Publications	144.99	
" Postage and stationery	152.69	
" Freight and express	610.95	
" Heat, light, water and power	767.08	
" Chemical and laboratory supplies	293.97	
" Seeds, plants and sundry supplies	1,763.42	
" Fertilizers	59.30	
" Feeding stuffs	3,865.14	
" Library	165.87	
" Tools, machinery and appliances	979.84	
" Scientific apparatus and specimens	122.65	
" Live stock	3,388.32	
" Traveling expenses	1,779.20	
" Contingent expenses	361.03	
" Buildings and repairs	6,045.44	
Total expenditures for the year		$27,399.22
By balance carried forward		582.54
Total		$27,981.76

STATEMENT E

Totals

TOTAL RECEIPTS AND EXPENDITURES OF THE OHIO AGRICULTURAL EXPERIMENT STATION FOR THE YEAR ENDING JUNE 30, 1911.

Dr.

Total Receipts

From United States Appropriations	$ 30,000.00	
" State Appropriations	200,090.00	
" Produce Fund	25,772.18	
Total receipts for the year		$255,862.18
Balance brought forward July 1, 1910		145,496,85
Total		$401,359.03

Cr.

By Expenditures

For Salaries	$65,527.95	
" Labor	40,554.12	
" Publications	8,464.90	
" Postage and stationery	1,923.43	
" Freight and express	3,773.43	
" Heat, light, water and power	4,337.90	
" Chemical and laboratory supplies	2,279.72	
" Seeds, plants and sundry supplies	11,181.10	
" Fertilizers	1,204.59	
" Feeding stuffs	8,686.76	
" Library	1,297.13	
" Tools, machinery and appliances	22,275.71	
" Furniture and fixtures	944.82	
" Scientific apparatus and specimens	2,880.80	
" Live stock	11,203.62	
" Traveling expenses	10,943.75	
" Contingent expenses	863.95	
" Buildings and repairs	42,209.95	
Total expenditures for the year		$240,553.63
By balance carried forward		160,805.40
Total		$401,359.03

Respectfully submitted,

W. H. KRAMER, *Bursar*.

REPORT OF THE DIRECTOR

HON. D. L. SAMPSON, *President of the Board of Control:*

SIR:—I have the honor of submitting the following report on the work of this Station for the year ended June 30th, 1911.

DEPARTMENTAL WORK

AGRONOMY

The work of the Department of Agronomy is being continued along much the same lines as last year, including work with the following field crops:—

Alfalfa—Seeding at different times and under different conditions as regards nurse and preparatory crops. Tests of seed from different sources. Plant-row work with strains propagated from hardy individual plants. The effect of disking alfalfa.

Clover—Comparative tests of red, mammoth, alsike, white and sweet clover. A comparison of early and late seeding, with and without harrowing. Effect of very deep and ordinary plowing on stand and yield of clover. Plant-row tests of many field selected plants.

Corn—Variety tests; rate of seeding; time of seeding; the value of the germination test as affecting crop yields; the economy of planting thick and thinning to the desired stand; the relation of certain ear characters to yield; ear-row tests; isolated breeding plots; ensilage variety tests and thickness of planting ensilage corn.

Special forage crops—A variety test of field peas and millets; tests of peas and oats at different rates of seeding, and tests of various legumes, including special tests with hairy vetch seeded alone and with rye.

Grasses—A comparison of ten prominent meadow grasses both as to yield and performance.

Oats—Manner of seeding relative to preparation of seed bed, early and late seeding; thickness of seeding; variety tests and plant-row tests.

Soybeans—A test of 50 varieties; a test of rate of seeding, varying from 1 to 8 pecks; a comparison of soybeans with cowpeas, and plant-row tests.

Wheat—Tenth-acre plot tests of over 60 varieties; hundredth-acre plot tests of over 100 varieties and pure line strains; extended work with individual plants in plant-row tests; studies of variation in pure lines of wheat with respect to size of kernel, size of head, tillering and protein content. A test of different grades of wheat as separated by the ordinary fanning mill. The relation of rate of seeding to yield. The relation of time of seeding to yield, and milling and baking tests.

Rotations and catch crops—A test of 20 different crops and crop combinations seeded in corn at last cultivation. A comparison of livestock with grain farming.

Heredity in plants—A special line of studies has been undertaken to determine whether heritable variations occur in pure lines of self fertilized plants. Wheat has been selected for these studies and, starting with a single head, the progeny will be followed through a number of generations to see whether extreme variations in any one of several characters may be fixed by selection.

ANIMAL HUSBANDRY

Horse feeding—The comparison of corn and oats as feeds for work horses (reported on in Bulletin 195) has been continued, and an experiment in fattening draft horses for market has been conducted.

Beef production—Different proportions of grain and roughage have been compared, and a ration of corn and clover hay has been compared with one of corn, cottonseed meal and clover hay. The Angus herd is still being used for the production of "baby beef."

Hog feeding—A number of supplements have been used in different proportions with corn in dry-lot feeding, and green feeds have been compared with each other and with dry feeds.

Sheep and wool—The production of wool and mutton is receiving more attention than in previous years. A wool laboratory, with scouring plant included, is to be provided during the present season, and fleeces from individuals in the breeding flock at the Southeastern Test-farm will be scoured to study individual variations in wool production. The flock at this Test-farm now consists of about 550 head of various ages, and a sheep and storage barn, 60 ft. x 68 ft., with a 24 ft. x 72 ft. stable wing has been erected which greatly facilitates the work in sheep husbandry. Cooperative experiments in shearing and washing have been undertaken with Messrs. A. O. and Howard J. Campbell, of Belmont.

Poultry—The work with poultry at the Southeastern Test-farm is being extended, a laying house 20 ft. x 60 ft. having been erected during the year. At Wooster 14 colony houses, 10 ft. x 20 ft., and

three smaller brooder houses, with yards and facilities for hatching have been provided and stocked, and experiments in meat and egg production are under way,

Work needed—There is need for exhaustive experimental work in the various phases of the horse industry, including the feeding and care of farm and city work horses, brood mares, foals and growing horses. This line of work involves large expenditures and hence has never been taken up in a thorough way. The fact that horses are scarce and high in price, is a good reason for taking up this line of work as soon and as thoroughly as possible.

Attempts to control the internal parasites of sheep have emphasized the fact that accurate knowledge along this line is very limited, and show the need of work in this phase of sheep husbandry.

BOTANY

The work of the Department of Botany has continued during the past year as outlined in my previous report. It has included, first, the examination of seeds for purity and germination and the identification of weeds with suggestions for weed control; second, investigation of plant diseases and methods for their control; and third, plant breeding work with tobacco and certain wheat hybrids. In the matter of seed examination it is hoped that the Station will soon be relieved of the inspection line of this work.

Weed spraying—The results of this work indicate that poison ivy, low willows, pawpaw ahd some other shrubby growths may be controlled by spraying. Further experiments are needed to determine whether horse nettle, Canada thistle and weeds of similar growth can be controlled in meadows and pastures without too much injury to the grass. The best spray thus far has been a solution of common salt, 3 pounds to the gallon of water.

Diseases of plants—Two bulletins on plant diseases have been published during the year: No. 228, entitled "Two recent important cabbage diseases of Ohio," and dealing with the Fusarium wilt and black-leg and foot-rot of cabbage, both of which have become destructive in the cabbage growing districts, and No. 229, "The Fusarium wilt and dry-rot of the potato", a prevalent disease of the potato, which affects both tops and tubers and is thus transmitted from year to year if infected seed is used. The work reported in these bulletins is being continued.

A serious, and as yet unsolved problem for the orchardists of southeastern Ohio has developed in the canker diseases of various kinds affecting the trunk and branches of bearing apple and pear

trees. These diseases are being carefully studied in the hope of finding some means for controlling them. Investigations are also being made in the diseases of forest and shade trees.

Plant breeding work on tobacco is being conducted in cooperation with the Bureau of Plant Industry, U. S. Department of Agriculture, and the results of this work for the past eight years are being prepared for publication.

CHEMISTRY

The work of this department is being conducted along the following lines:

Cooperative analyses—including analyses of grains, forage crops and grasses for the Department of Agronomy; of feeds and manure for the Department of Animal Husbandry; a study of the soils in the cultivated and mulched orchard plots in cooperation with the Department of Horticulture, and studies on the composition of manures reenforced with various materials, and determination of the amount of nitrogen carried to the soil by rain or snow, for the Department of Soil Fertility.

Soil chemistry—Investigations on the chemical composition of representative types of soil are being continued. While an invoice of the total amount of contituents present is obtained, the primary object in view is to secure basic information as to the total amount and availibility of phosphorus present in the soil, the effect of various soil treatments on the phosphorus content, and the relative value of different carriers of phosphorus, as measured by plant growth and the quantity of phosphorus taken up by the plant.

Plant physiological chemisty—This work includes the study of the absorption of plant nutrients by cereals, a report on which has been presented in Bulletin 221; investigations on the relation of the organic to the inorganic constituents of the wheat grain as influencing its quality, and a study of the influence of the sulphur supply in the soil on the proteid content of leguminous plants.

COOPERATION

The work of this Department of the Station includes the supervision of field experiments made by farmers in cooperation with the Station; a study of the methods of farm management and practice actually employed in the state; a general survey of the agriculture of the state, and the making of exhibits at county fairs.

Field experiments—The use of cooperative field experiments is limited almost exclusively to the determination of the adaptability of a given variety, crop, fertilizer or method to a plan which has been adopted for the management of the farm upon which the experiment

is made. A representative of the Department works out the details of the experiment somewhat in advance of planting time and makes such visits to the farm throughout the season as are necessary to superintend its execution. Ordinarily, however, such experiments will have a general application in the soil area in which they are located.

Farm management and farm practice investigations—The object of this work is to obtain definite knowledge concerning the methods of farm management and practice in vogue throughout the state, and by comparing these to assist the farmer in improving his methods and to furnish the Station with the data necessary to the application of the results of its work to actual farm conditions. In Circular 107 is reported the system of farm management practised on an alfalfa and truck farm in southeastern Ohio; Bulletin 227 furnishes data collected in a study of farm equipment, and Circular 111 is a study of the management of clover in corn belt rotations. This work is conducted in cooperation with the Office of Farm Management Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, which office contributes a part of the expense. Bulletin 227 and Circular 111 were prepared by members of the staff of the office mentioned.

An investigation on the production of milk in farm dairies has been in progress for several years, and studies are in progress concerning the swine and poultry industries.

Agricultural Survey—In my report for 1909 I called attention to the need for such definite information concerning the soil and other agricultural conditions of the state as would be furnished by an agricultural survey. With the expansion of the Station's work during recent years this need has become more and more urgent. The crop and other studies which have been mentioned above are so conducted as to contribute to such a survey, and the work is now to be supplemented by a reconnoisance survey of the soil types of the state, made by an expert of broad experience in this field of work.

County fair exhibits—Exclusive of the State Fair, at which the Station makes an exhibit covering 10,000 square feet in area, thirty or more county fairs will be reached this year by means of three exhibit outfits. A carload of material is required for the installation of each exhibit. Each outfit carries a tent 35 by 60 feet in size, which is used for housing the exhibit at such fairs as find it inconvenient to furnish a satisfactory building. The State Railroad Commission has kindly arranged for a uniform rating of the exhibit over most of the railroads in Ohio, and the railroad managements have

given especially fine service in almost every case. Without this co-operation on the part of the railroads it would be almost impossible to send each exhibit, as we do, to ten different fairs in as many weeks. An illustrated souvenir regarding the Station's work is being prepared for distribution at the different fairs.

DAIRYING

When the Station was removed to its present location it was planned to make dairying one of the leading features of its work. A large dairy barn was erected, a creamery was built and fully equipped, and foundation herds were established, including three of the distinctively dairy breeds. Within a few years, however, it was found that the cattle had become infected with tuberculosis, which made it necessary to dispose of most of the cows and suspend operations in the creamery. By the systematic use of the tuberculin test and thorough disinfection of the barnt he disease was completely eradicated, and a herd of sound animals was built up from the progeny of the diseased cattle, a work which required years for its accomplishment but which has demonstrated the practicability of eradicating this disease and maintaining a herd free from it, and thus has performed a greater service to the dairy industry of the state than could have been accomplished under the original plans.

Having completed this work the Station is now prepared to enter upon other lines of investigation in dairying, and it is important to so plan and conduct the work that it shall contribute to the solutions of the problems which confront the practical dairyman of today.

These problems lie along three principal lines: First, the production at a minimum cost of sound wholesome milk; second, the transportation of milk to point of manufacture or to city consumer without deterioration in quality; and third, the manufacture of milk into the highest quality of butter and cheese.

Experience has shown that the solution of these problems is by no means the simple proposition that it may seem to be to the casual observer. Eighteen years ago, in summing up the results of experiments in feeding dairy cows, made at this and other stations, I called attention to the futility of attempting to draw reliable conclusions from experiments made on a few individuals only, or extending over short periods of time. The progress of scientific investigation since that date has fully sustained the position then taken. We now know that no two plants of grass are exactly alike and that from the lowest to the highest organisms with which we deal in agriculture individual differences are so great that multitudes must be placed under observation before any law of general

application can be formulated, and if it were necessary to limit our study of dairy problems to the few cows which it is possible to keep at this Station it would be far better to leave this work altogether to institutions having larger resources.

The present prospect is, however, that our work need not be thus limited. Under a cooperative agreement between the Boys' Industrial School at Lancaster and the Experiment Station, the large dairy herd and splendid dairy barn of that institution have been placed at the service of the Experiment Station for investigational purposes; a service for which it is hoped that the Station may make some return by assisting in the elimination of inferior animals from the herd and in workIng out more economical systems of feeding and care.

Several of the pubic institutions of the state have facilities similar to those at Lancaster, and it would seem that it ought to be possible to effect a system of cooperation between them and the Station in this work which would be mutually advantageous.

But no mere physical equipment, however complete it may be in animals, buildings and apparatus, will serve the needs of the dairy industry of Ohio unless the work be conducted in the light which has been thrown upon it by recent progress in science, which is but another name for exact knowledge. Twenty years ago it might have been possible for any well informed, practical dairyman to conduct experiments that would have been helpful in the practical management of the dairy herd; but the methods of twenty years ago are obsolete today, and the man who can successfully conduct investigation in any of the various departments of agricultural research must have a far broader training than it is possible to obtain within the limits of the farm, for we now know that agencies unseen and utterly unsuspected a few years ago, have more to do with the success or failure of the farmer's operations than all his manipulation of the physical equipment of the farm.

ENTOMOLOGY

Orchard Spraying—Under the supervision of the Department of Entomology 125 acres or more of bearing orchards have been sprayed during the present season, for the purpose of determining the best methods of applying sprays for the control of codling moth, curculio and fungous diseases. The results of this work for the past four years have been summarized in Circular 112.

One of the orchards under test nas given an annual gross return per acre, through three seasons, of $429.25, of which at least 65 percent, was net gain over the cost of spraying, caring for the orchard, harvesting and marketing the fruit. The trees in

this orchard had been planted 15 to 25 years. Another orchard with somewhat younger trees and not so well located, has averaged $113.00 gross income per acre for four years, of which fully 70 per-cent was net. The present season promises to far surpass the preceding seasons in both volume and quality of fruit.

Of the different spraying materials used, the combination of lime-sulfur with arsenate of lead has given the best results, both fruit and foliage being more perfect when this spray was applied than when Bordeaux or other mixtures were used.

Peach, plum and cherry orchards have been sprayed with self-boiled lime-sulfur, combined with arsenate of lead, for the control of curculio and brown rot with excellent results. The commercial lime-sulfur, even when diluted with 60 to 100 parts of water, has been found a questionable spray to use upon peach trees, and severe injury has uniformly followed spraying peach trees with any form of copper or iron sprays.

Mill Insects—Experiments are being conducted in mill treatment for the destruction of such insects as injure mill products. Four mills were treated by the department the past spring, either by heating or by fumigating with hydrocyanic acid gas. Treatment of other mills has been arranged for, and seven mills have been treated according to specifications furnished by the department. One mill has installed a proper heating system and others will probably do so at an early date. Advice is furnished to mill owners concerning amount of radiating surface required, arrangement of pipes, etc.

Bark Beetles—Experiments in treatment for bark beetles have been continued along the lake shore and studies have been made in their life histories. The result of this work is to indicate that the measures recommended in Bulletins 194 and 196 will be found practically effective.

Wheat Joint-Worm—The results of investigations on this insect have been published in Bulletin 226, which furnishes much information that is new regarding the life history and habits of this insect and also furnishes conclusive data regarding the efficiency of most of the measures that have hitherto been recommended. Some of these recommendations are found to have been emphasized too strongly and others have not been made sufficiently prominent. Although this insect has been generally distributed over the state this season it seems not to have caused excessive injury except in very limited areas.

Hessian Fly—This insect caused an unusual amount of damage last fall, and had not the weather conditions been favorable to the wheat it would doubtless have caused widespread injury the present

season. Notwithstanding the favorable conditions, some neighborhoods have suffered severely from its work, and it is evident that late sowing will need to be the rule over most of the state for two or three seasons.

Chinch Bugs caused considerable injury to corn, chiefly in the northwestern counties, during the summer of 1910, and the weather conditions have so favored the development of this insect that a much more extensive outbreak is occuring the present season. A considerable fraction of the diminution of the wheat crop in 1911 should be charged to this insect.

Insects attacking the sugar beet—The sugar beet farms in Paulding and adjoining counties suffered severely the past spring from attacks of flea beetles. Occasionally fields of 15 to 20 acres were completely destroyed by them and had to be replanted. Some investigations were made on other insects feeding upon sugar beets, and a publication on this subject is contemplated.

The Sod Web-worm was very destructive to corn and wheat-fields in the western part of the state and a number of experiments have been conducted looking to their control.

Wooly Aphis—Owing to the uncertainty respecting appropriations for this year and the lateness of the date at which they finally became available we were obliged to discontinue work with the Woolly Aphis in Ohio nurseries.

FORESTRY

Five main lines of work have been pursued by this department during the past year, viz:

1. Cooperation with public institutions, possessing land, in the management of timber tracts, and the establishment of experimental and demonstrational plantations.
2. Cooperation with private owners in the improvement of the farm woodlot, and in the various operations of reforestation.
3. The establishment of nurseries for experimental purposes, and the distribution of forest tree seedlings in connection with various operations of cooperative work.
4. A forest survey, which includes a study of forest conditions throughout certain portions of the state.
5. Educational work, conducted through farmers' institutes, granges, picnics, exhibits at county fairs and work at educational institutions.

Cooperative forestry at public institutions—The nursery areas at the public institutions were enlarged by the addition of over 40,000 trees, including 33 different species.

During the year, five additional institutions of various classes have asked the Station to inaugurate forestry work on the farms in connection. The total number of institutions in cooperation with the department is now fourteen. About 21,000 trees of 27 species were planted in permanent plantations the past spring at the Boys' Industrial School at Lancaster, the Oberlin Municipal farm at Oberlin, the Cincinnati University at Cincinnati, and Miami University at Oxford. Topographical maps and working plans were made for the Boys' Industrial School at Lancaster, Kenyon College at Gambier, the Tuberculosis Hospital at Mt. Vernon and the Hospital for the Criminal Insane at Lima.

Cooperation with private owners—During the year 113,409 trees were distributed among private owners for experimental and demonstrational work in woodlot improvement and various phases of reforestation. This work showed a gratifying increase in applications for aid in woodlot management as compared with planted groves.

Nurseries—The principal forest nursery is located at Wooster on the Station farm. It contains about a million seedling trees. Last spring 400,000 seedling trees were purchased for nursery and permanent planting. About 125,000 were imported from Europe. The German shipment arrived in good condition and very little loss of stock occurred. One hundred and twenty-eight coniferous seed beds were established the past spring and about 400,000 seedlings have thus far been secured. The seed beds contain 14 species—all coniferous. An excellent germination was secured in the coniferous seed beds, but some injury resulted from "damping off" before it was brought under control.

Forest survey—A preliminary survey of forest conditions was made in central and western Ohio. This work consisted in the examination of the Station's cooperative groves, and the native woodlots. Either superficial or detailed examination was made of 2,365 woodlots in these counties. Studies were made of the catalpa and locust groves and data taken to determine their rate of growth.

The Fourth Annual Report on Forest conditions in Ohio has been recently issued as Bulletin 223, and is a detailed report of the operations of this department for the past year.

HORTICULTURE

The work of the Department of Horticulture during the year has been directed chiefly to the solutions of problems in apple culture.

In the Station orchards the study of varieties has been given considerable attention, while work in spraying, thinning and cultural methods has been carried on at the same time. A closely

planted apple orchard of early bearing sorts has been set for the purpose of securing maximum crops from a given area at as early a date as possible, and an orchard of dwarf apples has been planted.

The rejuvenation of old orchards—By far the most important work that this department has carried out in recent years has been conducted in the southeastern part of the state under the immediate supervision of Mr. Ballou, partial reports of which have appeared in Bulletins 217 and 224. This work was at first directed chiefly to spraying, and gratifying results were secured, not only in demonstrating the value of the methods employed, but also in awakening an earnest desire among the people to rejuvenate and care for their orchards. The effects attained later in the fertilizing of orchards, however, are so striking that it now seems probable that this phase of the work will yield even greater results than did the work in spraying.

Orchard demonstration work—Many applications are received for orchard demonstrations in spraying and pruning, but the Station's resources in men and funds do not justify it in undertaking work merely for demonstrational purposes, highly desirable though it is that the knowledge of better methods in orcharding should be extended as rapidly as possible; hence, unless a particular orchard offers opportunity for extending the Station's researches we cannot undertake work in it.

Orchard heating has been given considerable attention and some useful results have been secured, so as to determine the practicability of such work. The indications are that the heating of peach orchards in the winter is feasible, but it does not appear that orchard heating in the spring is so essential in Ohio as in some of the western states, and it seems probable that a less number of heaters per acre will be required here than there.

Vegetable gardening—Plant breeding has been carried on with vegetables both in the greenhouse and outside and encouraging results are being attained.

Ornamental gardening—The collections of ornamental trees, shrubs and other plants on the Station grounds are yearly increasing in interest and value.

Correspondence—More than 4,000 letters have been sent out by this department during the year, the greater part being in answer to inquiries regarding apple culture. A considerable number of these inquiries come from other states and refer to matters which show that the writers are looking towards Ohio as a suitable location for orcharding.

NUTRITION

The mineral nutrients in blue-grass—During the past year this department has published, in Bulletin 222, results of a study of the mineral nutrients in blue grass, from which it appears that some blue-grass pastures in Ohio contain twice as high percentages of the mineral nutrients as others, these differences being due to differences in the soils upon which the grasses were grown. It is also shown that the content of blue-grass in mineral nutrients may be very greatly increased by the use of fertilizers. There is every reason to believe that the grass on a soil which is rich in lime and phosphorus is a better food and will produce more bone especially, and also more muscle and more milk, than grass grown on unfertile soils.

Nutrient phosphorus compounds—The main line of investigation of the department has been a continuation of a study of the nutritive values of various compounds of phosphorus. This study was begun in the winter of 1907-8. Results obtained thus far have contributed materially to a knowledge of this subject, but a thorough understanding seems to require further work and a greater refinement and elaboration of method than any one has so far bestowed upon it.

Complete ash analyses of a considerable number of foods and feeding stuffs are being made and a search for improved methods of chemical analysis is always in progress. The methods of this department for the estimation of inorganic phosphorus in vegetable and animal substances, published in Bulletin 215, have received wide recognition and general adoption.

As a part of this investigation a review of the literature of phosphorus metabolism has been undertaken and is being prosecuted in various libraries. It already involves some thousands of articles.

Nutrition Building—To facilitate the work of this department the Station has erected a Nutriton Experiment Building, which provides adequately for the experimental work with live animals and also for slaughter and refrigeration and meat curing work.

The building with equipment has cost $22,000. It is 40x60 feet on the ground; two stories and a high basement, with brick walls, slate roof and concrete floors. The basement contains the refrigeration plant, a 20-ton ice machine and a tank for freezing ice, and also a workshop and a large room containing machinery for ice cutting, rendering and otherwise working up carcasses. The first story contains a large slaughter room for cattle, sheep and swine, and cooling rooms occupying a space of 30x38 feet and giving temperatures from 40° to 15° below zero F. The second floor contains a room

23x38 feet for metabolism experiments with animals and four smaller rooms for various purposes connected with this work. The animals are brought to this second floor by means of an elevator.

SOIL FERTILITY

The investigations on the maintenance of soil fertility have been continued along the lines indicated in my previous reports, and the work is being extended and strengthened by extending the field experiments to the county experiment farms; by enlarging the scope of the chemical investigations, which now include studies of the various soils under experiment and of the effect of different treatments of the soil upon the composition of the crop grown upon it; by the inauguration of biological studies of the soil, and by a reconnoisance survey of the soils of the state, undertaken by the Department of Cooperation.

In the case of the county experiment farms which have been established in Paulding and Miami counties, the problem will be the maintenance of the fertility of a productive soil, rather than the recuperation of an exhausted soil or the building up of a sterile soil, as at the main Station and at the Strongsville test farm; but the prevention of the insiduous wastes which have brought our worn soils to their present condition is a matter of even greater importance than their recuperation.

THE COUNTY EXPERIMENT FARMS

As has been stated above, experiment farms have been located in Miami and Paulding counties. The farm in Miami county contains 123 acres and lies two miles northwest of Troy. The topography is almost flat; over a large part of the farm the soil is black, while the slight elevations are yellow clay. The Paulding county farm lies a mile and a half south of Paulding, and contains 92 acres. the greater portion of the area being the flat, dark land common in that section. On both farms drainage is the first essential to profitable cultivation. On the Paulding county farm good outlets had been provided and about half the necessary tiling had been done. On the Miami county farm but little had been done except to provide the main outlets.

As a first step towards planning a system of experiment for these counties the following compilation has been made of the average areas in the principal crops in the two counties for the ten years, 1900-1909:

AVERAGE AREA IN DIFFERENT CROPS

	Miami acres	Paulding acres
Corn	54,291	46,710
Oats and Barley	23,084	35,854
Wheat and Rye	38,251	14.956
Meadows	10,291	17,454
Clover	12,328	7,352
Pasture	13,512	22,404
Woodland	13,445	20,765
Waste	3,472	2,967

In both counties corn is the leading crop, wheat taking second place in Miami and oats in Paulding. In both counties, however, there has been a tendency to reduce the area in wheat and increase that in oats during the 10-year period, due largely to the loss of wheat by freezing out on the flat lands which comprise the larger part of the area of both counties. The areas in rye and barley have been insignificant in both counties.

In both counties the predominance of each of the two principal cereals over the combined area in meadows and clover shows that crop rotation is not systematically followed.

In Paulding county the sugar beet crop has been introduced within recent years and is becoming an important feature of the county's agriculture, a large sugar factory having been erected at Paulding in 1909. In Miami county the tobacco crop has increased in area from 4,170 acres in 1900, to 7,275 acres in 1909.

In both counties the proportion of live stock to the area under cultivation is below that of the average of the state, indicating that a large proportion of the produce is sold off the farm.

Having these facts in view the following general scheme of experimentation has been proposed for the two county farms, and approved by the county boards of agriculture:

(1) Experiments designed to work out the most practical methods of maintaining and increasing the productiveness of the land, through crop rotation and the use of fertilizers and manure, these experiments being so planned as to articulate on the one hand with common practice in the county and on the other with the similar experiments in progress at the State Experiment Station and its several district test farms.

(2) Comparative tests of varieties of cereals and other crops, in order to determine which are best adapted to the soil and climatic conditions of the county.

(3) Experiments in feeding, having as their chief objects the utilization of the corn and crop residues—corn stover, straw, beet tops and pulp—in the production of meat, as against selling the grain and returning the crop residues to the soil.

(4) Experiments in orcharding, designed to determine the best varieties and systems of management for farm orchards under the local conditions of these counties.

(5) Experiments with special crops, of local importance, such as sugar beets in Paulding county and tobacco in Miami county.

Because of the prominence of the sugar beet industry in Paulding county it is proposed to devote a considerable part of the work of the experiment farm of that county to the study of this crop, although other interests will not be neglected.

PUBLICATIONS

The following publications have been issued during the year:

Bulletin 221, pp. 1-37. The composition of wheat. By J. W. Ames.

Bulletin 222, pp. 39-53. The mineral nutrients in bluegrass. By E. B. Forbes, A. C. Whittier and R. C. Collison.

Bulletin 223, pp. 55-116. Fourth annual report on forest conditions in Ohio. By C. E. Thorne, W. J. Green and Edmund Secrest.

Bulletin 224, pp. 117-150. The rejuvenation of orchards. By F. H. Ballou.

Bulletin 225, pp. 151-174. The farm grasses of Ohio. By C. G. Williams.

Bulletin 226, pp. 165-201. The wheat joint worm. By J. S. Houser

Bulletin 227, pp. 203-254. Farm equipment. By L. W. Ellis.

Bulletin 228, pp. 255-297. Two recent important cabbage diseases of Ohio. By Thos. F. Manns.

Bulletin 229, pp. 299-336. Fusarium blight and dry-rot of the potato. By Thos. F. Manns.

Bulletin 230, pp. 337-366 Annual report, meteorological summary, press bulletins and index.

Circular 103, June 12, 1910, 20 pp. Annual meeting of the Ohio State Horticultural Society, 1910.

Circular 104, August 15, 1910, 20 pp. Plans and summary tables of the experiments at the central farm, Wooster, on the maintenance of soil fertility.

Circular 105, September 1, 1910, 3 pp. Floats. By E. W. Gaither.

Circular 106, October 1, 1910, 2 pp. Seeding lawns and permanent pastures.

Circular 107, October 20, 1910, 19 pp. A successful alfalfa and truck farm in southeastern Ohio. By W. A. Lloyd.

Circular 108, January 25, 1911, 8 pp. Orchard practice. By W. J. Green.

Circular 109, February 1, 1911, 2 pp. Orchard spraying suggestions for 1911. By W. J. Green, A. D. Selby and H. A. Gossard.

Circular 110, February 25, 1911, 21 pp. Treatment of artificial tree plantations. By Edmund Secrest.

Circular 111, March 15, 1911, 19 pp. The management of clover in corn-belt rotations. By J. A. Drake.

Circular 112, April 30, 1911, 15 pp. Commercial apple orcharding. By H. A. Gossard.

Circular 113, June 20, 1911, 57 pp. Alfalfa in Ohio. By W. M. Cook.

Circular 114, June 24, 1911, 14 pp. Plans and summary tables of the experiments at the central farm, Wooster, on the maintenance of soil fertility.

Eight press bulletins have been issued during the year, Nos. 315 to 322 inclusive. These are republished with the present report.

PERSONNEL

Professor J. Warren Smith, Section Director of the Weather Service, has been appointed Climatologist of the Experiment Station.

Assistants Gail T. Abbot, Albert G. Woods, Jos. H. Gourley, A. C. Whittier and E. F. Timmerman have resigned to accept other positions and assistants have been appointed in the various departments as follows: Animal Husbandry, J. W. Hammond, Geo. R. Eastwood, and Ross Sherwood: Botany, W. O. Gloyer, Paul A. Davis and F. K. Mathis; Chemistry, J. A. Stenius; Cooperation, Geo. N. Coffey; Dairying, A. E. Perkins; Forestry, Geo. R. Green; Horticulture, Paul Thayer and Ernest J. Riggs; Nutrition, M. Helen Keith; Soil Fertility, Charles McIntire.

Mr. R. E. Caldwell has been transferred from the Department of Animal Husbandry to that of Dairying.

Respectfully submitted,

CHAS. E. THORNE,
Director.

APPENDIX

Bulletins

OF THE

Ohio Agricultural Experiment Station.

1910-1911

CONTENTS.

BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 230 JULY, 1911.

METEOROLOGICAL SUMMARY—PRESS BULLETINS—INDEX

METEOROLGICAL SUMMARY FOR 1910

BY C. A. PATTON

EXPLANATION OF TABLES

The following tables contain statistics of temperature, rainfall, etc., for the year, and are compiled from data obtained from daily observations. T stands for "trace"—less than .01 inch of rainfall. Temperature is given in degrees Fahrenheit.

Table I shows the daily rainfall at the station during the year in inches and hundredths.

Table II shows the daily mean temperature for each day of 1910 and the monthly mean temperature with the 23 years' average.

Table III gives the monthly mean temperature at the station with the 23 years' average for the same.

Table IV gives the monthly mean rainfall for the station with the 23 years' average for the same.

Table V gives the monthly mean temperature for the state for 1910 with 23 years' average.

Table VI gives the monthly mean rainfall for 1910 with the 23 years' average for the state.

Table VII gives the monthly mean temperature and rainfall for the station and state for 1910 with the 23 years' aveage.

Table VIII contains the mean temperature, the highest and lowest temperatures, with the range of temperature for each month; the number of clear, fair and cloudy days; the rainfall, snowfall and prevailing direction of wind, for both the station and state for 1910.

Table IX contains the principal points of interest on temperature, rainfall, and state of weather at the station during the year, and a grand summary for twenty-three years.

Table X contains the principal points of interest on temperature, rainfall, and state of weather for the state during the year and a grand summary for twenty-eight years.

Table XI gives the highest and lowest temperature for each month during the past twenty-three years, for both the station and state.

NOTES ON THE WEATHER AT THE STATION, 1910.
SUMMARY BY MONTHS

LATITUDE 40° 47′ 01″, LONGITUDE 81° 55′ 48″
ELEVATION ABOVE THE SEA 1,030 FEET

JANUARY.

The mean temperature for January was 26.7°, which is slightly below the station average for January. Cold weather continued throughout the month. The snowfall was heavy, and drifted badly in later part of month. The precipitation was 5.29 inches, which is 2.04 inches above the Station average for January.

FEBRUARY

The mean temperature for February was 23.8°, which is below the Station average for this month. Thirteen inches of snow fell on the 17th making a total of 18 inches on the ground at this time, followed by a week of cold weather, the mercury dropping as low as 12 degrees below zero on the 19th. The total snowfall for the month was 28.5 inches; this melted off with rain the last of the month causing high water.

MARCH

The mean temperature for March was 47.2° which is the highest mean temperature ever recorded for March at this station. The lowest minimum reached was 18° above zero on the 11th; the highest maximum was 84° on the 24th. The total precipitation was 1.00 inch which is the least amount of rainfall ever recorded for the month of March.

APRIL

The mean temperatnre for April was 50.2° which is 2° above the average for this month. The first part of the month was bright and warm bringing early fruit trees into bloom, followed by killing frosts and freezing on 8th, 10th and 13th and by eight inches of snow on the 19th. The latter part of month was cold and cloudy. The total precipitation was 3.22 inches.

MAY

The mean temperature for May was 54.7°. This low mean has only been equalled twice in the history of the station. Cold, cloudy weather continued throughout the month. Rain fell on twenty days. The total rainfall for the month was 4.87 inches which is above the average for May. A very heavy frost on the 6th killing most of the early fruit and berries.

JUNE

The mean temperature for June was 64.3° which is below the average for June. The first part of month was cold and rainy, the latter part was warm and bright with but little rainfall. The total precipitation was 2.57 inches which is 1.57 inch below the station average for June.

JULY

The mean temperature for July was 72.6° which is above the average for the month. The total precipitation was 1.12 inch which is more than three inches short of the average for July. The drought of the month very seriously injured the corn and all truck and garden crops. The rainfall is the least on record for July at this station.

AUGUST

The mean temperature for August was 70.9°. which is 1.4° above the average for this month. The rainfall for the month was far deficient, being only .95 inch. A maximum temperature of 94° was reached on the 15th and 16th. The drought continued throughout the month, all crops and vegetation suffering severely.

SEPTEMBER

The mean temperature for September was 65.3° which is slightly above the average for September. The long severe drought was broken by a heavy rainfall on the 24th amounting to 1.78 inch. The total precipitation for the month was 2.59 inches. Light frost occurred on the 10th, 15th and 16th doing no damage.

OCTOBER

The mean temperature for October was 54.9° which is above the average for October. Very high winds on the 4th were followed on the 5th and 6th by almost continuous rain for 40 hours, the total amount for this period was 3.92 inches. The total fall for the month was 5.24 inches, which is 2.83 inches above the average for October. The first killing freeze occurred on the 29th.

NOVEMBER

The mean temperature for November was 34.8° which is 5.2° below the average making this the coldest November on record. Cold weather continued the entire month with many days of light snowfall. The total fall for the month was 4.5 inches. The total precipitation was 2.36 inches, which is below the average for the month.

DECEMBER

The mean temperature for December was 24.4° which was 5.5° below the station average for December. This low mean for December has only been equalled once since 1888; in 1903 the mean for December was 21.7°. The snowfall for the month was 7.25 inches, some snow remaining on the ground the entire month. The total precipitation was 2.29 inches.

METEOROLOGY—TABLE I—RAINFALL

DAILY RAINFALL AND MELTED SNOW FOR 1910, AT THE EXPERIMENT STATION

Date	January	February	March	April	May	June	July	August	September	October	November	December	Date
1	.02	......	......	......	......	.15	......	......	T	......	T	.05	1
2	.04	......	......	......	.30	.07	......	T	......	......	.20	T	2
3	......	.20	......	T	.82	.30	T	......	......	......	T	.02	3
4	......	......	......	.06	......	T	......	T	.03	......	......	.03	4
5	.25	T	......	.20	......	......	......	......	......	1.50	.05	......	5
6	.50	......	.02	.12	......	.38	.07	......	T	2.35	.02	......	6
7	.30	......	.25	......	T	......	.17	T	......	.07	T	.02	7
8	......	......	......	......	.08	......	......	......	.19	......	......	T	8
9	.10	.50	......	......	.28	.05	......	.04	.18	......	......	......	9
10	......	......	......	......	......	.09	T	.28	......	......	.73	.05	10
11	......	.20	......	......	.25	1.07	......	......	......	......	.05	.05	11
12	.05	.20	......	......	......	.01	T	......	T	......	'02	.05	12
13	.39	......	.02	......	T	......	......	......	.25	......	T	.02	13
14	.58	......	.25	......	......	T	......	......	......	......	.05	......	14
15	......	......	......	T	......	......	T	......	......	......	T	T	15
16	......	.45	......	.04	......	......	.05	.15	......	T	......	......	16
17	.15	1.30	.05	.85	.24	......	T	.02	......	......	......	......	17
18	.81	......	......	T	.30	......	......	T	T	......	T	T	18
19	......	......	.02	.79	......	......	......	.02	......	......	......	.05	19
20	......	......	.29	.37	.36	......	......	......	......	......	......	T	20
21	.32	.12	......	.05	.23	......	..	......	......	.30	......	.05	21
22	.80	.09	.07	......	1.05	......	......	......	......	.60	.03	......	22
23	T	.05	......	.01	.02	......	......	......	T	......	.25	.36	23
24	T	......	......	.25	.14	......	......	......	1.78	T	.39	.03	24
25	......	......	......	......	.30	......	......	......	-03	.09	.02	T	25
26	.62	......	......	.40	.05	......	......	.44	......	......	......	......	26
27	.16	.90	......	.05	......	.08	.38	......	.13	.08	.25	......	27
28	......	.40	......	.02	......	.37	.45	......	......	.25	.07	.63	28
29	......	......	.03	.01	.14	......	......	......	......	T	.03	.58	29
30	20	......	......	......	.02	......	......	......	...	......	.20	.30	30
31	...	....	T	......	.29	......	......	......	......	......	......	......	31
Total	5.29	4.41	1.00	3.22	4.87	2.57	1.12	.95	2.59	5.24	2.36	2.29	
Average	.176	.157	.032	.107	.157	.086	.036	.031	.086	.169	.079	.074	

METEOROLOGY—TABLE II—TEMPERATURE

MEAN TEMPERATURE FOR EACH DAY OF 1910 AT THE EXPERIMENT STATION

Date	January	February	March	April	May	June	July	August	September	October	November	December	Date
1	30.0	21.5	43.5	48.5	62.0	43.0	74.0	65.0	67.0	61.5	50.5	28.5	1
2	37.5	34.5	41.0	51.5	67.0	55.0	73.5	70.5	64.5	54.0	43.0	25.0	2
3	28.0	34.0	39.0	55.5	60.0	46.0	74.5	77.0	75.5	64.0	36.5	27.5	3
4	14.0	29.5	41.0	65.5	46.0	51.5	71.0	77.5	72.0	73.5	34.5	28.5	4
5	27.0	28.5	50.0	65.5	41.5	60.0	68.5	65.5	79.5	70.0	30.5	23.5	5
6	26.0	15.0	53.5	59.0	42.5	58.0	73.0	65.0	76.5	57.5	32.5	26.0	6
7	17.5	15.0	46.5	39.0	48.0	55.5	78.5	64.0	68.5	50.5	30.5	19.5	7
8	12.5	34.0	34.5	43.0	61.5	54.0	73.0	69.5	71.0	50.5	41.5	20.5	8
9	16.0	30.0	32.5	52.0	57.0	58.0	77.0	70.5	65.0	49.0	45.5	18.5	9
10	13.0	20.0	33.5	47.0	52.0	55.5	76.5	73.5	52.5	54.5	47.5	15.5	10
11	13.5	13.5	33.5	57.0	54.0	57.0	72.5	67.5	61.5	54.0	33.5	26.5	11
12	30.0	21.0	42.5	52.5	42.5	57.5	75.5	65.0	67.5	54.5	32.0	22.0	12
13	38.0	19.0	46.0	43.5	43.5	61.5	72.5	82.0	60.5	53.5	33.5	20.0	13
14	29.0	25.0	31.5	49.5	42.0	63.0	68.0	76.5	58.5	63.0	33.5	25.0	14
15	25.5	37.5	30.0	57.0	44.0	65.5	72.5	74.5	54.0	63.5	31.0	27.0	15
16	25.5	33.0	39.5	57.0	51.0	67.5	76.5	75.5	56.0	63.0	33.5	16.5	16
17	30.0	16.0	35.5	53.0	59.5	70.0	71.5	76.0	60.0	65.0	31.5	16.0	17
18	37.5	11.5	47.0	44.5	59.5	77.5	65.0	74.0	64.0	66.5	28.0	23.0	18
19	31.0	8.5	52.0	42.5	59.5	75.5	63.5	68.0	69.5	63.5	30.0	33.5	19
20	37.0	19.5	50.0	37.5	62.0	73.5	64.5	63.5	72.0	63.5	28.0	21.5	20
21	34.0	36.0	42.5	46.0	69.0	73.0	70.0	72.0	68.0	65.5	30.0	12.5	21
22	22.5	28.0	52.0	46.0	68.0	72.5	73.5	70.0	61.0	50.5	33.0	15.5	22
23	27.0	16.5	55.5	49.5	67.0	73.5	76.0	74.0	74.0	46.0	36.5	30.5	23
24	26.0	6.0	61.0	39.5	62.0	74.0	79.0	79.0	69.0	47.0	37.0	28.0	24
25	24.5	8.5	56.0	47.0	57.0	66.5	83.0	77.5	70.0	48.5	40.5	19.0	25
26	38.0	29.5	54.0	42.5	52.5	72.5	71.5	66.5	65.0	47.0	34.5	29.0	26
27	37.5	37.5	60.5	48.5	50.0	71.0	73.5	56.5	66.5	50.0	29.5	27.5	27
28	32.0	38.5	69.5	43.0	58.5	78.5	71.0	63.5	57.0	35.5	35.0	37.5	28
29	26.0	......	62.0	55.5	62.0	68.5	71.5	67.0	55.5	32.0	32.0	40.5	29
30	28.0	......	67.0	67.5	53.5	73.0	74.0	75.5	58.5	36.0	28.0	30.0	30
31	25.5	......	59.0	.....	42.0	......	67.5	76.0	......	47.5	......	20.5	31
Monthly mean	26.7	23.8	47.2	50.2	54.7	64.3	72.6	70.9	65.3	54.9	34.8	24.4	
23-year average	27.4	26.4	37.6	48.2	58.3	67.5	71.2	69.4	63.9	51.1	40.0	30.2	

METEOROLOGY—TABLE III

MONTHLY MEAN TEMPERATURE FOR TWENTY-THREE YEARS AT WOOSTER

Temperature in degrees Fahrenheit

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Dat
1888	23.0	28.8	31.7	46.3	57.7	68.9	70.1	67.8	57.1	44.9	40.7	31.4	47.3	1888
1889	31.1	22.9	38.7	47.1	57.8	64.5	70.0	66.0	60.8	45.3	39.3	40.7	48.6	1889
1890	36.0	36.6	30.9	48.4	56.0	69.8	70.5	65.8	59.6	50.0	41.3	28.8	49.5	1890
1891	30.0	34.0	32.0	49.0	52.0	68.0	68.0	71.0	68.0	49.0	38.0	37.0	49.6	1891
1892	22.0	33.0	33.0	47.0	57.0	70.0	70.0	69.0	61.0	49.0	38.0	28.0	48.0	1892
1893	18.0	28.0	38.0	50.1	57.6	69.3	72.0	67.9	63.2	52.3	37.7	30.9	48 7	1893
1894	32.8	26.7	43.5	50.5	57.5	67.9	71.4	69.2	66.1	52.3	36.5	32.9	50.6	1894
1895	21.9	17.9	32.4	49.5	59.4	69.9	68.6	70.9	66.5	44.2	40.4	32.8	47.8	1895
1896	27.9	29.2	29.8	54.6	64.5	65.6	70.2	68.5	60.6	45.8	44.4	30.6	49.3	1896
1897	24.0	30.0	39.3	47.2	53.4	64.3	73.2	67.0	66.7	55.9	40.7	31.8	49.4	1897
1898	31.6	27.4	43.3	45.3	58.2	68.7	74.5	71.1	66.2	52.6	38.4	27.9	50.4	1898
1899	26.6	21.3	35.0	52.1	60.0	69.4	70 0	71.0	61.6	55.0	43.2	29.0	49.5	1899
1900	30.2	25.0	31.8	47.8	61.5	68.5	72.6	74.0	67.1	58.9	40.6	30.7	50.7	1900
1901	28.3	20.0	39.1	45.2	57.9	69.1	75.9	71.6	63.3	51.7	36.6	26.1	48.7	1901
1902	26.3	21.4	41.2	46.2	61.2	65.6	73.0	66.4	62.7	53.9	47.3	28.7	49.5	1902
1903	24.4	29.0	45.7	48.0	62.2	63.0	71.8	68.8	64.4	58.2	36.8	21.7	49.1	1903
1904	18.6	20.5	37.6	42.8	59.4	67.0	69.8	66.7	64.2	50.4	39.6	28.1	47.1	1904
1905	22.6	19.8	41.2	46.8	59.2	68.0	71.6	70.0	63.8	51.0	38.3	33.1	48.8	1905
1906	35.9	25.8	30.2	51.9	59.9	68.8	71.0	74.2	67.7	51.4	40.4	31.2	50.7	1906
1907	30.8	24.6	44.9	41.7	52.8	64.6	69 9	68.6	65.0	47.4	38.5	32.1	48.4	1907
1908	28.7	26.8	43 1	50.1	62.2	68.1	72.4	69.0	66.4	53.0	41.0	31.7	51.0	1908
1909	31.7	33.6	35.9	48.4	57.9	69.3	69.6	70.4	62.2	47.8	48.3	25.2	50.0	1909
1910	26.7	23.8	47.2	50.2	54.7	64.3	72.6	70.9	65.3	54.9	34.8	24.4	49.2	1910
Average:	27.4	26.4	37.6	48.2	58.3	67 5	71.2	69.4	63.9	51.1	40.0	30.2	49.2	

METEOROLOGY—TABLE IV

MONTHLY RAINFALL FOR TWENTY-THREE YEARS AT WOOSTER

Rainfall—Inches

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Date
1888	3.52	2.43	3.34	2.48	3.82	2.31	4.54	4.35	1.92	3.18	4.95	1.39	3.18	1888
1889	4.33	2.42	2.13	1.58	2.97	4.86	6.73	1.98	4.05	1.36	3.53	3.93	3.32	1889
1890	4.71	6.20	4.37	3.10	6.01	5.57	2.67	4.66	5.12	7.45	2 61	1.74	4.51	1890
1891	2.74	4 83	3.71	1.66	2.24	7.13	3.28	1.85	0.94	1.33	5.73	2.92	3.20	1891
1892	2.67	2.67	3.38	2.44	7.69	7.89	4.73	2.69	3.20	0.37	2.06	1.74	3.46	1892
1893	4.01	6.33	1.89	5.66	6.28	2.51	1.38	1.53	1.85	5.18	2 49	1.50	3.38	1893
1894	2.19	3.37	2 36	1.74	4.41	2.23	1.38	0.76	4.07	2.53	2.41	3.15	2.55	1894
1895	3.92	1.00	1.98	1.69	1.38	4.20	2.19	2 30	3.92	1.15	4.21	3.51	2.65	1895
1896	1.73	2.27	3.67	3.34	3.41	3.98	8.05	1.96	5.16	0.71	1.78	2.41	3.21	1896
1897	2.82	2.64	2.81	2.75	4.97	2.98	3.89	3.86	0.29	0.89	5.76	2.50	3.01	1897
1898	4.10	2.27	6.44	2.56	4.60	2.70	6.79	5.53	2.15	4.25	4.14	2.29	3.99	1898
1899	3.29	1.64	3.95	1.28	4.42	1.95	3.73	0.53	5.56	2.21	1.59	2.78	2.74	1899
1900	2.78	2.74	2.25	1.70	2.23	3.71	5.65	5 97	2.19	2.10	4.30	0.99	3.05	1900
1901	1.58	1.20	3.09	2.46	4.32	4.82	3.32	3.58	5.64	0.81	1.62	3.47	2.99	1901
1902	0.63	0.83	2.99	1.46	2.57	5 55	5.26	1.87	3.49	1 52	2.62	4.07	2.74	1902
1903	3.54	3.69	3.29	4.55	1.59	3.69	4.61	6.58	2.07	2.63	2.25	1.95	3.37	1903
1904	5.27	3.90	6 22	6.59	4.45	1.67	4.93	2.03	2.27	0.87	0 40	2.68	3.44	1904
1905	1.83	1.36	2.61	2.51	5.97	7.50	5.14	4.47	5.10	2.32	2.04	2.08	3.58	1905
1906	1.93	1.06	3.57	2.27	2.98	3.81	4.93	7.38	5.16	3.55	2.39	3.77	3.57	1906
1907	6.92	1.09	5.80	2.69	3.48	3.81	3.96	2.04	3.13	2.34	1.33	3.41	3.33	1907
1908	1.96	3.89	5.02	3.64	4.56	2.17	3.44	3.17	0.73	1.22	1.09	3.05	2.83	1908
1909	2.95	5.22	3.02	3.92	4.06	6.44	4.05	5.21	1.73	2.16	2.91	2.55	3.68	1909
1910	5.29	4.41	1.00	3.22	4 87	2.57	1.12	0.95	2.59	5.24	2.36	2.29	2.99	1910
Average	3.25	2.92	3.43	2.84	4.06	. 09	4.16	3.27	3.14	2.41	2.81	2.62	3.25	

METEOROLOGY—TABLE V

MONTHLY MEAN TEMPERATURE FOR TWENTY-THREE YEARS FOR THE STATE

Temperature in degrees Fahrenheit

Date	January	February	March	April	May	June	July	August	September	October	November	Decmeber	Year	Date
1888..........	24.3	30.5	34.2	49.2	59.1	70.4	72.1	70.4	60.3	47.9	42.9	33.3	49.5	1888
1889..........	33.3	25.8	40.2	49.9	60.2	66.7	72.5	69.1	62.9	47.9	41.0	43.8	51.1	1889
1890..........	38.8	39.4	34.5	51.3	59.2	73.3	73.1	68.8	62.1	52.7	43.9	31.2	52.3	1890
1891..........	33.0	36.0	35.0	52.0	58.0	71.0	69.0	70.0	67.0	51.0	40.0	39.0	51.7	1891
1892..........	24.0	35.0	35.0	49.0	59.0	73.0	73.0	71.0	64.0	52.0	38.0	29.0	50.1	1892
1893..........	18.0	29.0	38.0	50.2	58.3	70.6	74.5	70.7	65.2	53.7	39.3	32.7	51.6	1893
1894..........	37.7	28.9	45.1	50.6	60.0	71.3	74.3	71.2	67.8	53.9	37.5	33.9	52.3	1894
1895..........	23.4	19.6	35.5	51.7	61.1	70.2	71.6	73.5	69.0	46.9	41.3	33.9	49.9	1895
1896..........	29.4	30.5	32.4	56.7	67.9	69.5	73.2	71.8	62.7	49.0	45.1	32.9	51.7	1896
1897..........	25.5	32.4	41.5	49.3	46.3	68.1	75.5	69.4	66.9	58.1	42.2	32.8	50.6	1897
1898..........	32.4	30.0	45.0	47.2	61.0	71.9	76.0	73.5	67.8	53.1	38.8	28.8	52.1	1898
1899..........	27.8	21.6	36.9	53.3	63.3	71.5	74.1	73.7	64.1	57.4	43.9	30.2	51.5	1899
1900..........	31.1	26.0	32.9	50.1	62.9	69.8	74.1	76.3	69.3	60.5	41.6	31.6	52.3	1900
1901..........	29.2	21.1	39.5	46.7	59.0	70.9	78.1	73.1	64.8	53.8	37.7	27.9	50.2	1901
1902..........	27.3	22.3	41.9	48.2	62.6	66.9	74.0	67.4	63.6	54.6	48.5	29.4	50.5	1902
1903..........	27.1	29.9	46.7	49.9	63.9	64.4	72.9	70.7	65.6	54.0	37.2	23.4	50.5	1903
1904..........	20.7	22.9	39.7	44.4	60.7	68.4	71.4	68.8	65.5	52.2	40.5	28.6	48.6	1904
1905..........	22.7	20.8	42.7	48.5	60.7	69.2	73.0	71.7	65.3	52.6	39.6	32.9	50.0	1905
1906	35.7	27.3	31.3	52.1	61.3	69.8	72.1	74.6	68.9	52.7	41.1	32.3	51.6	1906
1907..........	32.2	27.7	45.9	42.5	54.5	65.6	72.6	69.5	65.5	48.8	39.1	33.0	49.6	1907
1908..........	29.1	26.0	43.4	51.0	62.8	69.2	73.9	71.2	68.0	54.1	41.7	33.1	52.1	1908
1909..........	32.2	34.7	37.3	49.1	58.7	70.1	66.4	72.1	63.7	49.1	49.4	26.1	50.7	1909
1910..........	28.2	26.3	48.9	52.0	56.5	66.2	73.8	71.3	67.0	57.2	36.6	25.5	50.8	1910
Average	28.8	27.9	39.3	49.8	59.9	69.5	73.1	71.3	65.5	52.7	41.2	31.5	50.9	....

METEOROLOGY—TABLE VI

MONTHLY RAINFALL FOR TWENTY-THREE YEARS FOR THE STATE

Rainfall—Inches

Date	January	February	March	April	May	June	July	August	September	October	November	December	Year	Date
1888........	3.65	1.74	3.55	1.99	3.77	3.41	4.40	5.16	2.27	3.98	4.25	1.47	3.30	1888
1889........	3.13	1.35	1.50	1.79	3.71	4.13	4.25	1.50	3.62	1.78	4.02	2.81	2.79	1889
1890........	4.91	5.25	5.29	3.15	5.52	4.50	1.99	4.70	5.56	4.27	2.53	2.37	4.17	1890
1891........	2.82	4.91	4.19	2.13	2.20	4.82	3.82	3.07	1.50	1.76	5.00	2.39	3.21	1891
1892........	2.05	3.27	2.16	2.63	4.63	6.73	3.13	6.15	1.27	0.67	2.62	1.85	3.09	1892
1893........	2.56	5.13	2.09	6.37	4.97	3.34	2.49	2.17	1.57	4.24	2.09	2.61	3.30	1893
1894........	2.14	2.79	2.16	2.31	4.00	2.65	1.56	1.67	3.31	2.01	2.17	2.98	2.47	1894
1895........	4.00	0.69	1.59	2.11	1.80	2.44	2.00	2.96	1.66	1.22	4.11	3.85	2.37	1895
1896........	1.67	2.25	3.34	2.78	2.67	4.81	8.11	3.38	5.13	1.20	2.63	1.65	3.29	1896
1897........	1.93	3.64	5.17	3.27	3.93	2.85	4.65	2.72	0.78	0.64	6.62	2.39	3.21	1897
1898........	5.25	2.32	6.23	2.38	4.10	2.86	3.98	4.50	2.56	3.72	3.17	2.71	3.65	1898
1899........	3.01	2.11	4.66	1.68	4.32	2.96	4.18	1.82	2.69	2.14	1.72	3.16	2.87	1899
1900........	2.37	3.53	2.35	1.89	2.40	2.99	4.62	3.68	1.76	1.89	4.15	1.24	2.74	1900
1901........	1.70	1.24	2.66	3.40	3.96	4.38	2.73	3.32	2.86	0.73	1.54	3.79	2.69	1901
1902........	1.42	0.88	2.76	2.21	3.09	7.48	4.69	1.67	4.55	2.28	2.60	3.95	3.13	1902
1903........	2.36	4.95	3.51	4.01	2.82	3.97	3.67	3.20	1.52	2.62	2.10	2.07	3.07	1903
1904........	3.85	2.69	5.73	2.64	3.79	2.88	4.13	2.74	1.95	1.50	0.37	3.09	2.95	1904
1905........	1.73	1.58	2.50	3.10	5.63	4.72	3.93	4.46	2.86	3.63	2.63	2.25	3.25	1905
1906........	1.98	1.16	3.97	1.89	2.17	3.41	5.14	4.77	2.92	3.19	2.59	3.68	3.07	1906
1907........	6.11	0.85	5.55	2.74	3.47	4.57	5.36	2.48	3.92	2.76	1.93	3.16	3.57	1907
1908........	1.82	4.10	2.43	3.69	4.72	2.52	4.08	2.59	0.58	1.17	1.06	2.33	2.84	1908
1909........	3.24	5.39	2.77	4.13	4.72	5.86	3.90	3.68	1.56	2.46	1.93	2.68	3.53	1909
1910........	4.74	4.45	0.25	2.93	4.07	2.98	3.53	1.46	3.60	4.13	1.62	2.41	3.01	1910
Average	2.98	2.88	3.32	2.84	3.76	3.97	3.93	3.21	2.60	2.35	2.76	2.65	3.11	....

METEOROLOGY—TABLE VII

MEAN TEMPERATURE AND RAINFALL AT THE STATION AND FOR THE STATE, 1910 AND FOR TWENTY-THREE YEARS

Temperature in degrees Fahrenheit. Rainfall in inches.

	January	February	March	April	May	June	July	August	September	October	November	December	Year
Mean temperature at the Station, 1910	26.7	23.8	47.2	50.2	54.7	64.3	72.6	70.9	65.3	54.9	34.8	24.4	49.2
Twenty-three years' average temperature at the Station	27.4	26.4	37.6	48.2	58.3	67.5	71.2	69.4	63.9	51.1	40.0	30.2	49.2
Mean temperature for the State, 1910	28.2	26.3	48.9	52.0	56.5	66.2	73.8	71.3	67.0	57.2	36.6	25.5	50.8
Twenty-three years' average temperature for the State	28.8	27.9	39.3	49.8	59.9	69.5	73.1	71.3	65.5	52.7	41.2	31.5	50.9
Rainfall at the Station, 1910	5.29	4.41	1.00	3.22	4.87	2.57	1.12	0.95	2.59	5.24	2.36	2.29	2.99
Twenty-three years' average rainfall at the Station	3.25	2.92	3.43	2.84	4.06	4.09	4.16	3.27	3.14	2.41	2.81	2.62	3.25
Rainfall for the State, 1910	4.74	4.45	0.25	2.93	4.07	2.98	3.53	1.46	3.60	4.13	1.62	2.41	3.01
Twenty-three years' average rainfall for the State	2.98	2.88	3.32	2.84	3.76	3.97	3.93	3.21	2.60	2.35	2.76	2.65	3.11

METEOROLOGY—TABLE VIII.

SUMMARY BY MONTHS.

	Temperature											Number of days				Precipitation in inches			
	Mean	Highest	Date	Lowest	Date	Range	Mean daily range	Greatest daily range	Date	Least daily range	Date	Clear	Fair	Cloudy	Rainfall .01 or more	Monthly rainfall	Average daily rainfall	Monthly snowfall	Prevailing wind
AT THE STATION																			
January	26.7	45	*26	—1	*8	46	16.0	28	10	8	28	2	5	24	16	5.29	.176	24.50	S. W.
February	23.8	48	16	—12	19	60	20.9	47	20	6	17	5	3	20	11	4.41	.157	28.50	S. W.
March	47.2	84	24	18	*11	66	28.3	48	4	12	*2	15	5	11	9	1.00	.032	1.00	S. W.
April	50.2	81	5	23	13	58	26.8	51	14	11	20	11	3	16	14	3.22	.107	9.25	N. W.
May	54.7	82	28	25	6	57	23.1	47	28	8	24	8	6	17	17	4.87	.107	.....	N. W.
June	64.3	90	*23	35	8	67	24.9	38	8	7	28	16	5	9	10	2.57	.086	.....	N. & W.
July	72.6	94	25	44	20	50	25.8	41	20	13	13	22	9	0	5	1.12	.036	.....	S. W.
August	70.9	94	*15	38	27	56	29.8	43	20	18	*18	23	6	2	6	0.95	.031	.....	S. W.
September	65.3	91	5	34	10	57	25.7	43	11	11	27	13	9	8	7	2.59	.086	.....	N. W.
October	54.9	85	3	24	*29	61	25.1	42	3	11	28	12	7	12	8	5.24	.169	.25	S. W.
November	34.8	66	9	14	20	52	14.5	41	9	3	16	0	5	25	15	2.36	.079	4.50	N. W.
December	24.4	49	28	0	22	49	16.0	35	31	4	6	0	4	27	15	2.29	.074	7.25	N. W.
Sums and averages	49.2	94	July *25	—12	Feb. 19	56	23.1	51	Apr. 14	3	Nov. 16	127	67	171	133	2.99	.099	75.25	S. W.
FOR THE STATE																			
January	28.2	62	26	—24	10	86	....	50	..	..	..	5	7	19	14	4.74	.153	20.40	S. W.
February	26.3	68	27	—25	19	93	....	60	..	..	..	10	6	12	10	4.45	.159	23.90	S. W.
March	48.9	90	24	12	15	78	....	54	..	..	..	16	12	3	2	0.25	.008	.20	S. W.
April	52.0	88	*5	19	8	69	....	58	..	..	..	10	10	10	12	2.93	.098	.23	S. W.
May	56.5	88	2	21	6	67	....	53	..	..	..	10	11	10	14	4.07	.131	.....	S. W.
June	66.2	97	*23	33	4	64	....	44	..	..	..	13	11	7	10	2.98	.099	.....	S. W.
July	73.8	98	*2	42	19	56	...	44	..	..	..	15	13	5	9	3.53	.114	.....	S. W.
August	71.3	98	15	36	27	62	....	49	..	..	..	19	10	3	5	1.46	.047	.....	S. W.
September	67.0	93	5	34	10	59	....	45	..	..	..	13	11	6	9	3.60	.120	.....	S. W.
October	57.2	94	3	18	30	76	....	56	..	..	..	18	7	5	6	4.13	.133	.25	S. W.
November	36.6	78	1	11	20	67	....	49	..	..	..	6	6	17	8	1.62	.054	2.41	W.
December	25.5	63	29	—10	25	73	....	43	..	..	..	7	6	18	11	2.41	.078	10.50	S. W.
Sums and averages	50.8	98	July *2	-25	Feb. 19	71	...	60	..	..	.	142	110	115	110	3.01	.099	57.80	S. W.

*On other dates also

METEOROLOGY—TABLE IX

SUMMARY BY YEARS AND GRAND SUNMARY FOR TWENTY-THREE YEARS AT WOOSTER

	1888	1889	1890	1891	1892	1893	1894	1895
AT	WOOSTER					EXPERIMENT STATION		
Mean temperature	47.6°	48.6°	49.5°	49.9°	48.°	48.7°	50.6°	47.8°
Highest temperature		91.5° *1	94.5° Aug. 3	99.° Aug. 8	98.° July 25	95.° *5	98.° July 19	98.° June 4
Lowest temperature	—5° Feb. 9	—5° *2	1.° Mar. 2	0.° Mar. 1	—20° Jan. 20	—9° Jan. 11	—7° Dec. 28	—6.° *8
Range of temperature		96 5°	93.5°	99.°	118.°	104.°	105.°	104.°
Mean daily range of temperature		18.7°	18 9°	21.°	19.°	20.2°	22.9°	21.8°
Greatest daily range of temperature		42° Apr. 23	41.° Jan. 13	42.° Sept. 23	46.° July 17	45.° Aug. 9	45.° July 31	55.° Oct. 6
Least daily range of temperature		2° Jan. 6	4.5° *3	4 ° Feb. 8	4.° *4	3.° *6	4.° *7	1.° Nov. 22
Number of clear days		125	109	116	116	96	127	125
Number of fair days		103	119	110	123	164	154	117
Number of cloudy days		137	137	125	98	105	84	123
Number of days rain fell		119	149	119	119	129	130	102
Total yearly rainfall	38.23 inches	39.87 inches	54.21 inches	38.36 inches	41.46 inches	40.61 inches	30.60 inches	31.45 inches
Greatest monthly rainfall	4.51 inches	6.73 in. July	7.45 in. Oct.	4.26 in. June	7.89 in. June	6.33 in. Feb.	4.41 in. May	4.21 in. Nov.
Least monthly rainfall	1.39 inch.	1.36 in. Oct.	1.74 in. Dec.	1.95 in. April	1.37 in. Oct.	1.38 in. July	0.76 in. Aug.	1.00 in. Feb.
Prevailing direction of wind	S.	S.	S.	S.	S. W.	S. W.	S. W.	W.

*1 July 10 and Sept. 1. *2 Feb. 23 and 24. *3 Jan. 8 and Sept. 10. *4 March 5, Nov. 1, 3 and 25, Dec. 1 and 18. *5 July 7, 25 and Sept. 7. *6 Jan. 24, Feb. 11, May 26. *7 Dec. 1 and 21.

METEOROLOGY—TABLE IX. Continued

SUMMARY BY YEARS AND GRAND SUMMARY FOR TWENTY-THREE YEARS AT WOOSTER

	1896	1897	1898	1899	1900	1901	1902	1903
AT	EXPERIMENT STATION							
Mean temperature	49.6°	49.4°	50 4°	49.5°	50.7°	48.7°	49.5°	49.1°
Highest temperature	93.° Aug. 9	3.° *10	96.° July 3	95.° Aug. 20	95.° July 4	95° *12	97.° May 4	94.° *14
Lowest temperature	−6° Feb. 19	−18° Jan. 26	−9° Feb. 2	−21° Feb. 10	−10° Feb. 27	−11° Dec. 21	−9° Feb. 5	−9.° Feb. 19
Range of temperature	99.°	114.°	105.°	116.°	105.°	106.°	106.°	103.°
Mean daily range of temperature	19 °	21.5°	20.3°	22 9°	20.6°	20.1°	21.3°	21.6°
Greatest daily range of temperature	43.° May 8	49.° Oct. 5	50.° Nov. 14	52.° Oct. 24	43.° May 6	43.° April 30	45.° May 4	48.° Nov. 8
Least daily range of temperature	3.° *9	0.° Feb. 6	5.° *11	3.° Feb. 18	2.° Nov. 20	2.° April 20	4.° *13	3.° *15
Number of clear days	130	124	133	126	149	152	183	148
Number of fair days	106	123	104	114	68	66	49	58
Number of cloudy days	130	115	128	125	118	147	133	159
Number of days rain fell	134	123	134	116	132	142	140	121
Total yearly rainfall	38.47 inches	36.16 inches	47.85 inches	32.93 inches	36.61 inches	35.91 inches	32.86 inches	40.44 inches
Greatest monthly rainfall	8.05 in. July	5.76 in. Nov	6.79 in. July	5.56 in. Nov.	5.97 in. Nov.	5.64 in. Nov.	5.55 in. June	6.58 in. Aug.
Least monthly rainfall	0.71 in. Oct.	0.29 in. Sept.	2.15 in. Sept.	0.53 in. Aug.	0.99 in. Dec.	0.81 in. Oct.	0.63 in. Jan.	1.59 in. May
Prevailing direction of wind	S W.	S. W.	N. W.	N. S. W.	S. W.	S. W.	S. W.	S. W.

*8 Jan. 12, 13 and Feb. 5. *9 Jan. 10 and March 8. *10 July 5 and 6. *11 Jan. 21, March 2 and Dec. 18. *12 July 1, 22 and 28.

METEOROLOGY—TABLE IX—Concluded.

SUMMARY BY YEARS AND GRAND SUMMARY FOR TWENTY-THREE YEARS AT WOOSTER.

	1904	1905	1906	1907	1908	1909	1910	Summary for twenty-three years
AT	EXPERIMENT STATION							
Mean temperature	47.1°	49.°	50.6°	48.4°	51.0°	50.0°	49.2°	49.2°
Highest temperature	92° July 17	92.° July 17	92.° June 29	90.° Aug. 12	95.° *17	90.° Sept. 14	94.° *19	99° Aug. 8, '91
Lowest temperature	—21.° Jan. 5	—12. Feb. 14	—14.° Feb. 7	—14° Jan. 27	—3° Feb. 9	—11 Jan. 13	—12° Feb. 19	—21.° *20
Range of temperature	113.°	104.°	106.°	104.°	98.°	101°	106°	120.°
Mean daily range of temperature	21.5°	20.8°	20.6°	20.8°	23.°	21.4°	23.1°	20.9°
Greatest daily range of temperature	48.° Dec. 28	42.° *16	40.° April 18	42.° Jan. 20	49.° Sept. 18	43° *18	51° April 14	55.° Oct. 6, '95
Least daily range of temperature	0.° Dec. 25	2.° Dec. 18	2.° Jan. 18	4.° Aug. 6	5.° Dec. 13	3.° Dec. 14	3.° Nov. 16	0.° *21
Number of clear days	149	144	130	109	141	114	127	130
Number of fair days	47	44	60	58	78	76	67	91
Number of cloudy days	170	177	175	198	147	175	171	140
Number of days rain fell	136	118	142	138	117	144	133	129
Total yearly rainfall	41.28 inches	42.93 inches	42.80 inches	40.00 inches	33.94 inches	44.22 inches	35.91 inches	39.00 inches
Greatest monthly rainfall	6.59 in. April	7.50 in. June	7.38 in. Aug.	6.92 in. Jan.	5.02 in. Mar.	6.44 in. Jan.	5.29 in. Jan.	8.05 in. July '96
Least monthly rainfall	0.40 in. Nov.	1.36 in. Feb.	1.06 in. Feb.	1.09 in. Feb.	0.73 in. Sept.	1.73 in. Sept.	0.95 in. Aug.	.29 in. Sept. '97
Prevailing direction of wind	S. W	S.	S	N. S. W.	S. W.	S. W.	S. W.	S. W.

*13 Jan. 22 and April 28. *14 July 4 and 9. *15 Jan. 4, Nov. 27 and Dec. 6. *16 April 9 and May 2. *17 Aug. 3, Sept. 24 and 25. *18 May 8 and Oct. 9. *19 July 25 and Aug. 15 and 16. *20 Feb. 10, 1899 and Jan. 5, 1904. *21 Feb. 6, 1897 and Dec. 25, 1904.

METEOROLOGY—TABLE X.

SUMMARY BY YEARS AND GRAND SUMMARY FOR TWENTY-EIGHT YEARS FOR THE STATE.

FOR THE STATE	1883	1884	1885	1886	1887	1888	1889
Mean temperature	49.4°	50.6°	48.0°	49.6°	51.4°	49.5°	51.1°
Highest temperature	98.° Aug. 22	98.° *1	101.° July 21	98.6° July 18	108.° July 18	102.° Aug. 3	99.5° Aug. 31
Lowest temperature	—17.2° Jan. 22	—34.° Jan. 25	—31.5° Jan. 29	—21.5° Jan. 12	—21.° Jan. 7	—15.° Jan. 27	—13.5° Feb. 24
Range of temperature	115.5°	133.°	132.°	120.1°	29.°	117.°	113.°
Greatest daily range of temperature	55.2° Mar. 18	50.° *2	58.5° Jan. 30	57.° Dec. 11	57.° Dec. 11	50.°	53.° Mar. 30
Average number of days rain fell	146	145	148	131	121	125	118
Mean yearly rainfall	44.98 inches	40.19 inches	30.08 inches	36.71 inches	33.63 inches	39.64 inches	33.53 inches
Mean daily rainfall	.123 inch	.110 inch	.104 inch	.100 inch	.092 inch	.108 inch	.092 inch
Prevailing direction of wind	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.
	1890	**1891**	**1892**	**1893**	**1894**	**1895**	**1896**
Mean temperature	52.4°	52.0°	50.0°	50.1°	52.4°	49.9°	51.8°
Highest temperature	103.1° Aug. 3	101.° Aug. 10	103.° July 25	102.° July 19	105.° *4	106.° July 20	103. Apr. 17
Lowest temperature	—4.° Mar. 7	—8.° Mar. 2	—25.° Jan. 20	—24° Jan. 11	—27° Dec. 29	—24.° Feb. 6	—18.° *6
Range of temperature	107.1°	109.°	128.°	126.°	132.°	130.°	121.°
Greatest daily range of temperature	48.5° Apr. 11	50.° *3	51.° Sept. 25	54.6°	60.° Oct. 19	59.° *5	53.° Mar. 25
Average number of days rain fell	149	120	121	113	100	89	124
Mean yearly rainfall	50.33 inches	38.61 inches	37.16 inches	39.63 inches	29.75 inches	28.46 inches	39.58 inches
Mean daily rainfall	.138 inch	.060 inch	.102 inch	.108 inch	.081 inch	.070 inch	.108 inch
Prevailing direction of wind	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.

*1 Sept. 28 and Oct. 1. *2 Sept. 5 and Dec. 4. *3 April 27 and 30. *4 July 18 and 19. *5 Jan. 15 and March 29. *6 Feb. 20 and 21.

METEOROLOGY—TABLE X—Concluded

SUMMARY BY YEARS AND GRAND SUMMARY FOR TWENTY-EIGHT YEARS FOR THE STATE

FOR THE STATE	1897	1898	1899	1900	1901	1902	1903	1904
Mean temperature	50.6°	52.°	51.5°	52.°	50.2°	50.6°	50.5°	48.6°
Highest temperature	113.° July 4	105.° July 1	105.° Sept. 6	103.° *8	109.° July 22	100.° July 8	104.° July 25	99.° *10
Lowest temperature	—27° Jan. 26	—20.° Feb. 3	—33.° Feb. 10	—20.° *9	—20.° Feb. 23	—17.° Feb. 14	—20.° Feb. 19	—30.° Jan. 4
Range of temperature	140.°	125.°	144.°	123.°	129.°	117.°	124.°	129.°
Greatest daily range of temperature	67.° *7	....	....	57.° Feb. 9	61.° Dec. 14	56.° May 4	60.° Sept. 25	54.° Jan. 5
Average number of days rain fell	110	121	107	107	107	114	111	117
Mean yearly rainfall	38.54 inches	43.78 inches	34.51 inches	32.87 inches	32.98 inches	37.58 inches	39.87 inches	35.36 inches
Mean daily rainfall	.105 inch	.119 inch	.094 inch	.090 inch	.090 inch	.103 inch	.109 inch	.096 inch
Prevailing direction of wind	S. W.	S. W	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.
	1905	1906	1907	1908	1909	1910	Summary for twenty-eight years	
Mean temperature	50.0°	51.6°	49.6°	52.1°	50 7°	50.8°	50.7°	
Highest temperature	100.° July 10	101.° Aug. 21	98.° July 22	104.° Aug. 3	97.° July 30	98.° *11	113.° July 4, '97	
Lowest temperature	—20.° Feb. 3	—23.° Feb. 6	—19.° Feb. 6	—22.° Feb. 9	—20° Dec. 30	—25.° Feb. 19	—39° Feb. 10, '99	
Range of temperature	120.°	124.°	117.°	126.°	117.°	123.°	152.°	
Greatest daily range of temperature	57.° May 24	54.° Oct. 13	57.* Feb. 13	60.* Oct. 5	51.°	60.°	67.° Sept. '97	
Average number of days rain fell	118	124	129	111	124	110	120	
Mean yearly rainfall	39.02 inches	36 87 inches	42.90 inches	34.09 inches	42.32 inches	36.17 inches	37.47 inches	
Mean daily rainfall	.107 inch	.101 inch	.117 inch	.092 inch	.116 inch	.099 inch	.101 inch	
Prevailing direction of wind	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.	S. W.	

*7 Sept. 25 and 26. *8 July 4, Aug. 6 and 10. *9 Jan. 20 and Feb. 27. *10 July 17 and Sept. 29. *11 July 2 and Aug. 15.

METEOROLOGY—TABLE XI.

MONTHLY MAXIMUM AND MINIMUM TEMPERATURE FOR TWENTY-THREE YEARS—FOR WOOSTER.

Date	January		February		March		April		May		June		July		August		September		October		November		December	
	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest
1888	..	-5	..	-1	..	8	..	19	..	31	..	42	..	43	..	41	..	31	..	27	..	21	..	9
1889	54	12	54	-5	71	16	80	21	90	30	87	38	92	49	90	45	92	37	76	23	65	16	65	18
1890	66	5	65	14	60	1	74	23	83	30	88	46	94	45	95	40	88	38	81	30	66	24	48	15
1891	51	12	60	3	61	0	83	21	82	28	89	44	89	49	99	53	98	42	88	25	71	10	58	16
1892	54	-20	54	6	65	10	76	28	86	38	90	56	98	48	92	49	88	36	81	25	67	16	61	-2
1893	51	-9	47	-2	75	10	83	24	84	36	92	45	95	47	93	37	95	28	85	24	66	15	62	6
1894	56	1	64	-1	75	14	92	24	83	35	93	37	98	41	96	41	93	36	80	28	65	31	57	-7
1895	54	-6	60	-6	59	9	80	21	94	27	98	35	92	42	94	42	93	34	73	19	72	18	61	-2
1896	53	-2	58	-6	65	4	89	19	86	44	87	39	92	45	93	41	92	34	71	21	69	13	56	1
1897	61	-18	54	0	69	11	79	21	78	31	88	37	96	50	92	42	96	28	86	25	65	12	60	2
1898	64	-1	64	-9	71	12	77	16	81	32	90	40	96	45	90	46	90	38	86	24	66	13	56	1
1899	55	-6	57	-21	67	9	86	21	86	30	92	40	94	45	95	39	94	32	92	22	66	22	63	-2
1900	54	-5	65	-10	57	-4	78	20	89	25	90	44	95	44	94	49	89	41	86	30	69	6	55	11
1901	53	-4	40	0	69	-1	82	22	92	33	91	38	95	50	94	47	86	34	79	26	67	18	64	-11
1902	47	2	59	-9	69	9	83	24	97	29	89	39	93	46	88	40	85	32	77	27	72	24	60	-5
1903	60	-8	63	-9	76	21	74	19	89	27	88	41	94	42	92	43	89	32	79	26	71	9	49	-2
1904	60	-21	57	-10	74	13	72	12	88	33	88	44	92	46	90	42	89	31	83	19	68	15	63	-1
1905	59	-8	43	-12	79	10	77	23	82	31	89	38	92	50	90	46	87	36	80	23	61	16	52	13
1906	72	6	65	-14	61	-5	80	21	86	29	92	47	88	46	91	48	90	44	74	22	72	23	58	6
1907	67	-14	50	-5	82	12	78	15	81	29	89	40	88	40	90	43	88	34	82	22	55	18	56	9
1908	51	4	56	-3	75	21	80	24	89	30	91	36	92	46	95	43	95	28	84	24	68	17	59	7
1909	66	-11	60	-2	60	12	81	13	84	31	89	42	89	45	89	41	90	30	81	22	72	21	66	-6
1910	45	-1	48	-12	84	18	81	23	82	25	90	35	94	44	94	38	91	34	85	24	66	14	49	0
Extremes....	72	-21	65	-21	84	-5	92	12	97	25	98	35	98	40	99	37	98	28	92	19	72	6	66	-11

METEOROLOGY—TABLE XI.—Concluded.

MONTHLY MAXIMUM AND MINIMUM TEMPERATURE FOR TWENTY-THREE YEARS FOR THE STATE

DATE	January		February		March		April		May		June		July		August		September		October		November		December	
	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest
1888	68	−15	69	−10	77	−6	92	19	91	23	102	34	97	42	102	35	92	26	80	22	81	17	63	1
1889	61	1	70	−14	82	10	88	15	96	26	92	38	98	47	100	40	99	28	83	17	77	9	73	10
1890	75	1	73	1	69	−4	86	20	92	28	101	39	101	43	103	40	92	33	85	29	77	17	65	3
1891	65	3	80	−2	74	−5	95	15	93	25	98	40	95	41	101	39	99	36	93	20	76	0	66	9
1892	61	−25	74	1	80	6	90	14	99	28	101	47	103	40	99	45	96	34	89	20	76	8	70	−12
1893	63	−24	68	−14	87	−8	93	20	94	23	102	40	101	42	101	37	100	24	95	15	76	1	72	−5
1894	66	−16	76	−15	91	3	97	16	98	31	102	29	105	36	104	36	103	27	90	15	79	4	70	−27
1895	62	−19	70	−24	86	−7	90	16	102	19	105	29	106	34	103	31	105	25	84	8	85	5	79	−13
1896	70	−4	78	−18	73	−7	103	15	99	36	98	23	102	39	102	35	100	25	85	17	79	7	67	−15
1897	71	−27	72	−9	82	5	92	11	91	25	102	31	113	44	101	38	105	25	97	20	76	8	71	−7
1898	71	−18	72	−20	84	5	87	10	92	29	99	39	105	38	100	40	102	38	96	20	76	2	67	−18
1899	66	−15	67	−39	76	0	94	6	96	28	102	36	105	41	104	39	107	26	94	20	79	18	69	−7
1900	67	−20	80	−20	70	−9	87	15	97	20	96	38	103	38	103	40	100	33	93	23	80	..	65	−2
1901	67	−10	60	−20	84	−8	91	18	90	26	103	30	109	48	101	42	98	29	88	20	79	10	73	−19
1902	63	−11	66	−17	82	−4	90	17	98	24	98	33	100	43	97	37	94	24	88	21	87	17	63	−11
1903	73	−13	69	−20	85	11	88	10	93	22	95	35	104	42	101	38	98	26	93	15	88	2	57	−11
1904	70	−30	75	−18	86	−1	81	7	95	27	98	37	99	41	97	38	99	23	92	15	75	0	69	−16
1905	65	−17	54	−20	85	−5	89	12	93	26	99	34	100	44	98	41	95	30	89	20	71	10	58	2
1906	79	−14	72	−23	74	−12	91	18	94	24	100	34	98	43	101	43	98	36	91	18	82	14	68	−15
1907	75	−23	66	−19	96	−2	86	10	89	24	98	36	98	37	96	40	93	29	88	19	71	11	69	2
1908	69	−8	66	−22	85	12	91	16	96	25	100	33	102	42	104	37	100	23	90	15	77	5	68	−2
1909	74	−17	70	−17	70	6	90	13	91	24	96	36	97	40	96	35	94	25	96	16	80	15	75	−20
1910	62	−24	68	−25	90	12	88	19	88	21	97	33	98	42	98	36	93	34	94	18	78	11	63	−10
Extremes...	79	−30	80	−39	96	−12	103	6	102	19	105	29	113	34	104	31	107	23	97	8	88	0	79	−27

PRESS BULLETINS.

The following press bulletins have been issued during the year:

No. 315. July 18, 1910. THE OHIO AGRICULTURAL EXPERIMENT STATION EXHIBIT AT THE COUNTY FAIRS.

The Ohio Experiment Station has just issued Circular 101, descriptive of the fair exhibits which are now being sent out annually to a number of county fairs. The issuance of this circular commemorates, in a sense, the holding of the first agricultural fair in America, which was held at Pittsfield, Mass., just one hundred years ago; in the summer of 1810.

The Station made exhibits at county fairs as early as 1891, and did so occasionally until 1905, when the general policy of making fair exhibits was adopted. Since that year, when seven fairs were visited, the requests for the exhibit have been so numerous as to make it necessary last year to send out duplicate exhibits, which reached twenty fairs. In all, fifty exhibits have been made in forty counties. For this year three exhibits are being prepared, which will reach twenty-six fairs in the following counties: Allen, Ashtabula, Athens, Auglaize, Belmont, Champaign, Coshocton, Greene, Guernsey, Hamilton, Hancock, Hardin, Harrison, Lorain, Lucas, Marion, Medina, Mercer, Miami, Morrow, Muskingum, Putnam, Scioto, Seneca and Washington and the State Fair, at Columbus.

The material composing the exhibits is not entered in competitive classes. It is not a display of fine products. It is illustrative of the experiment work of the Station. Each feature is a graphic presentation of some great truth. These truths are so presented as to make a most enduring impression on the mind of the visitor. One illustration will show the character of the whole exhibit: In the display last year was placed the entire product of two apple trees which stood in the same orchard only 30 feet apart—one sprayed and the other unsprayed. The remarkable difference in both quantity and quality of the fruit spoke for better orchard methods in more eloquent terms than the platform speaker or the printed page could employ.

The exhibit is accompanied by representatives of the Station and others familiar with its work to explain the exhibit and tell the farmers, and others interested, of the work of the Station. The Station has provided a large 35x60 foot tent under which to display the exhibit. There is no charge and every one interested is welcome. Every farmer in the above named and in nearby counties should make an effort to see the exhibit this year.

The illustrated circular is being sent to the regular mailing list and to others upon request to the OHIO EXPERIMENT STATION, Wooster, Ohio.

No. 316. July 25, 1910. THE FUSARIUM BLIGHT OR WILT OF POTATOES.

The Department of Botany is making a study of the Fusarium Blight (wilt) and Dry Rot of potatoes. During the early spring a press bulletin was sent out calling attention to the disease in the seed potatoes. In order to keep our

correspondents alert as to the nature of the disease and the possible losses it may occasion, and further to obtain fuller data as to the extent and the amount of this disease throughout the potato districts, this press bulletin is being sent out.

At this stage of growth the earliest symptoms are beginning to show. To those not familiar with this disease as a field trouble, a careful description of the symptoms is here given.

PRELIMINARY SYMPTOMS

The presence of the wilt disease is usually conspicuous when the plants are ten to fourteen inches in height. The preliminary symptoms are a light green color on the lower leaves, accompanied during the heat of the day by wilt and upward and inward rolling of the upper leaves. The color gradually changes to a yellow which slowly and evenly covers the affected vines. The early infected plants are usually quite evenly scattered throughout the field, showing evidence of disease dissemination by the seed, later the amount of yellowing rapidly increases and the large number of infected plants give the field a mottled appearance, which is very different from the even green color so characteristic of healthy, vigorous plants. The progress of the disease in the field is greater in certain areas than in others, due probably to different factors among which may be previous soil infection, irregular drainage, conditions favorable for the disease, so unfavorable for the potato crop.

PREMATURE DYING

The subtle and persistent nature of the disease is such as to mislead even the plant pathologist. The general effect of the wilt is to shorten the life of the crop, bringing about a surprisingly early maturity.

The later symptoms of the trouble are quite characteristic. The earliest infected leaves, viz., the lowest, die first, dropping vertically alongside of the stem, the joint breaking, the leaf being held to the stem by only a small part of the cuticle below. The upper leaves usually do not drop, but droop over upon wilting.

Plants, which are early and severely attacked, quickly wilt during the first few days of hot, dry weather. The root systems of wilted plants rot quickly, making it possible to pull up the affected vines easily.

The invasion of the tuber by the fungus usually takes place by way of the tuber-bearing stems, after the plant has wilted. The depth to which the fungus penetrates the stem end of the tuber is indicated by the brown area, shown by cutting thin sections across the stem end of the tuber. At digging time the depth of infection seldom exceeds one-fourth inch. However, should the potatoes be placed in warm storage, the fungus quite rapidly penetrates deeper.

FURTHER DATA DESIRED

This disease has only recently been recognized as a severe field trouble in this state. We have obtained data from last year's field conditions and from the potatoes carried over in storage and those used for seed the present season, which indicates that the Fusarium wilt is quite general, and that it is playing an important part in yield reduction throughout the state. We wish to increase this data and in order to do so we ask the cooperation of all interested in the potato crop. The following are some of the points we desire answered: (1) Is the disease prevalent in your vicinity? (2) What percent of the hills in your field are affected? (3) Did the potatoes show the dry rot in your storage? (4) At end of season we would like reports of yields.

If you are in doubt as to whether the symptoms showing in your potatoes are those of the Fusarium blight or not, send in yellowing or wilted plants, including roots. The Department will, by means of cultures, quickly determine it for you.

No. 317. September 12, 1910. SOW WHEAT A LITTLE LATE THIS FALL. By H. A. Gossard.

A little more Hessian fly than usual has been found scattered over the state this season and since we have had no general outbreak of this pest for some years and its parasites may therefore be presumed to be somewhat scarce, it will be best for Ohio farmers to sow a trifle late rather than early this fall. The normal date for sowing in northern Ohio is from the 15th to the 22nd of September, for central Ohio a week or ten days later, and for southern Ohio the last few days in September, or a little better, during the first two weeks of October. By the *normal* date we mean the date which will produce the largest yield, providing that no insect pests overturn the natural expectation. The normal date for sowing is determined, not by the entomologist, but by the agronomist, and rests upon the average results of sowing grain upon any given date through a long period of years. Only occasionally is it advisable for the entomologist to advise that there be a departure from seeding at the normal time. There is generally no danger, even from Hessian fly, if sowing does not precede the normal date, and at present we think it hardly necessary to suggest any further departure from the normal custom than to say that if departed from at all, this fall, the seeding should be in the direction of a week to ten days later than usual, rather than that much earlier. The dry weather will doubtless operate to destroy many of the pupae or "flaxseeds" of the Hessian fly by dessication and in those sections where the drouth has been severe and long continued there is probably no need for special apprehension.

We have become satisfied that no calculable advantage is gained against the wheat joint worm by departing from the normal date, either in the direction of early or late sowing. The degree of infestation will depend upon the stage of development reached by the grain at the time the eggs are laid by the jointworm fly in spring. Sometimes the early sown grain proves best, and again it is the late which proves most exempt. On the average it will be best to sow at the normal time and having given proper attention to preparation of the seed bed and to fertilizing, abide the result. Stiff, heavy-strawed varieties will stand the attacks of both Hessian fly and joint worm better than small, weak-strawed varieties. In some neighborhoods where jointworm is exceptionally severe it may be advisable to substitute rye for wheat.

No. 318. September 12, 1910. TREAT SEED WHEAT FOR SMUT. MUCH DISEASE IN 1910 CROP.

To treat seed wheat for stinking smut of kernels before sowing the grain seems very necessary in 1910. Reports received at the Ohio Experiment Station indicate that the smut is present in nearly every county of Ohio in this year's wheat crop.

This smut is caused by the spores of the stinking smut fungus which adhere to otherwise healthy seed-grain. These smut spores may come from smutted kernels broken open, or from bags or mills. There seem to be differences in the tendency or susceptibility of different varieties to smut, but the real problem is *to sow disinfected seed, or seed free from smut*. It is not likely that seed wheat free from smut can be easily purchased in Ohio at this time.

To treat seed wheat the method of sprinkling it with a solution of formaldehyde (formalin) in water (1 pint or pound of formaldehyde to 40 gallons of water) is recommended and is successful. The formaldehyde is on sale at drug stores.

Sprinkle piles of grain on tight floor or canvas with this solution by means of sprinkler, meanwhile shoveling the grain over so that every kernel is moistened—it will require three-fourths gallon to one gallon of solution per bushel of grain. When grain is so treated, allow to lie in pile 2 to 3 hours or over night: then spread to dry. After treating, handle the grain in *disinfected bags*, *mills*, and *drills*.

To disinfect fanning mills or drills, wash or sprinkle all parts well with the same, or stronger formaldehyde solution. To disinfect bags for handling treated seed grain, soak them over night in same solution used to treat seed wheat.

For treating seed wheat in large quantities in tight elevators, etc., it is possible to use a gaseous formaldehyde method which is described in the Spray Calendar, Bulletin No. 199. The sprinkling method above given is also described in the same Bulletin, which will be sent you upon application.

No. 319. October 10, 1910. SMALL TOOLS ON THE FARM.

If the average farmer were asked "How much money have you invested in the small tools on this farm?" it is probable that after a moment of thought, during which he would have a mental picture of an axe, a hand-saw, a grindstone and rather a confused idea that there was a lot of stuff of one sort or another somewhere about the farm, would reply that from, $25 to $50 would cover the cost.

A recent investigation conducted by the Ohio Experiment Station in cooperation with the U. S. Department of Agriculture discloses that this is far short of the mark. In order to arrive at some conclusion in regard to this matter, careful inventories were taken on thirty-three Ohio farms, and in every instance the total amount was many times what the owner had "guessed."

The fact that these small tools are bought, one at a time as needed, and are not cared for systematically, leads to a very erroneous idea of their value. Summarizing the inventories of these thirty-three farms, it is estimated that to completely equip a general farm of 160 acres in Ohio with small tools will probably cost from $200 to $300, or in excess of the farmers' "guess" by more than 500 percent. An error in judgment of this amount, particularly when the error is against the farm, is serious enough to challenge our attention.

Even on farms where inventories are habitually taken, these tools of minor equipment are usually included as "other small tools" and given a guessed at value, somewhat after the stereotyped expression appearing on sale bills: "other articles too numerous to mention."

Farm requirements differ very greatly, the highly specialized farm not needing nearly so many tools as the general farm. The necessity of a fairly complete outfit is apparent if the farmer would avoid expensive trips to town or to the neighbors to meet some immediate need, thereby stopping teams and laborers until the repair is affected. The advantage of some systematic arrangement is also apparent, in order that the exact tool may be at hand when wanted and thus avoid loss and delay by reason of mislaid, borrowed, stolen or lost tools.

Some of these tools can be charged to special farm enterprises, as to the horses, the dairy, corn, hay, grain, etc., but by far the great majority constitute an overhead charge against the farm. The connection between an augur bit handle and a bushel of wheat may not be at once apparent to the miller, but it requires the auger bit handle, to turn the bit, to bore the hole in the plank, to make the wagon-jack, to grease the wagon that hauled the grain to the machine, and that brought the wheat to the mill. Before the bushel of wheat can yield a profit it must help pay for the auger bit handle and the other minor tools which total a hundred or more dollars in value on any well managed farm. The item is small but it is a part of that great overhead charge which exists on every farm and which goes to help make up the difference between what the farmer gets and what some people think he gets.

The inventories of the thirty-three farms investigated are summarized and discussed in Circular 98 of the Ohio Experiment Station, and the articles are so classified and arranged as to make it easy for any farmer to compare the list with those found on his own farm. This Circular will be sent free upon request.

No. 320. November 28, 1910. MICE INJURY TO FOREST TREES.

For some years catalpa, mulberry and other trees commonly grown, have suffered considerable injury by the attacks of field mice. During the winter months these rodents gnaw the bark about the base of the trees to a greater or less degree, which frequently results in a complete girdle. When girdling occurs below the root crown the trees usually die. The amount of injury varies with the severity of the winter, although a season rarely passes without reports of occurence. During the winter of 1909-10, characterized by deep snows and severe cold, ravages to an extent heretofore unknown were reported from all sections of the state.

PREVENTION OF INJURY

There are no practical means of exterminating field mice, although certain operations are helpful in preventing their attacks on trees. It has been observed that injury is greater and more general where dead grass, mulch or debris of any kind lies close to the trees. Material of this nature affords a harboring place, from under which cover mice prefer to operate. Before winter sets in all grass or mulch material of any kind should be raked away from the trees for a radius of at least two feet, leaving the ground as bare as possible. Where mulch culture is used a foot or two about each tree should be left bare. Injury is more severe on those trees whose root systems set high on the ground; that is, in cases where freezing and thawing have caused heaving. Such trees afford cavities in which mice harbor, and complete girdling usually results fatally if below the point where root and stem join. Throwing a few shovelfuls of dirt about the trees has given satisfactory results.

Trees which have been more than half girdled should be cut off an inch above the root collar and sprouts allowed to grow from the stumps. In the case of trees over three or four years of age all sprouts may be permitted to stand the first season, and all but the most thrifty removed the winter following. In some cases all but the most thrifty may be removed when a foot high. The one remaining must be staked in order to prevent its breaking off or becoming distorted.

Mice injury in some cases has caused a large percentage in loss of trees, particularly in catalpa groves, and parties possessing these groves will doubtless profit by taking precautionary measures in preventing as far as possible the attacks of these rodents.

No. 321. March 13, 1911. HAVE YOU TESTED YOUR SEED CORN?

The testing of seed corn, while always a matter of safety, has seldom been so necessary as it is this spring of 1911.

When husked last fall corn carried much more than the normal amount of moisture. Twenty-seven to thirty percent was not at all uncommon. This in itself would have been cause enough for alarm if normal temperature had prevailed. But November of 1910 had the lowest mean temperature of any November during the 23 years of the Experiment Station's records. Very early in November mercury dropped to 10° below freezing and day after day it was from 10° to 18° below freezing. These two factors are without a parallel in recent years and should give the corn growers no little concern.

Three weeks ago this Station wrote to prominent corn growers in all parts of the State for samples of corn from 100 representative ears which had been saved for seed, or for reports of germination tests already conducted by them. The samples received in response to this call have been germinated and reveal a condition which was expected. The range of germination is from 45 to 96 percent, much seed which had been handled with considerable care showing below 80 percent.

Such a state of affairs will result in a very poor and uneven stand of plants in Ohio corn fields, unless every ear of corn intended for seed be carefully tested to determine whether it will grow.

In conducting the germination test it is important that the conditions which the corn will have to endure in the field be duplicated as nearly as possible. Condemn every ear of low vitality to the feed trough, where it will prove of some value, but if used for seed will cause a loss of from $1.50 to $5.00.

What can the corn grower do that will make him any more money than to weed out these worthless seed ears?

No. 322. April 17, 1911. PREVENT THE ONION SMUT WHEN THE SEED IS SOWN.

The fungus disease commonly known as *onion smut* becomes exceedingly troublesome in the soil of fields on which onions have been grown continuously for a number of years. The spores of the onion smut live for a considerable time in the soil when this once becomes infected. It is present in much of the onion land of north-eastern Ohio, and elsewhere in the state.

The smut affects only onions which are grown from seed, attacking the seedling plants shortly after germination or soon after they appear above ground and many plants, not destroyed entirely by the smut, are injured to such an extent that they will die later or else develop with an abnormal bulb filled with spores of the disease. When onion sets or seedlings, grown under glass or in uninfected soil, are planted in smut-infected ground the smut does not attack them, indicating that the fungus is able to penetrate the plant only through its most delicate tissues.

The smut spores of the disease are spread by cultivators or other implements; frequently by the wind for short distances; on the feet of men and horses, and by decaying onion refuse which is often used as a fertilizer. The Ohio

Experiment Station has discovered and applied a successful treatment of the soil with a formalin solution to prevent onion smut. This solution is made with 1 pound of 40 percent formaldehyde (commercial formalin) to from 25 to 33 gallons of water. For old infected fields it is well to use the more concentrated solution. This is applied best with a drip attachment to the seed drill, and at the rate of 120 to 150 gallons of the solution per acre for field onions, and from 500 to 700 gallons for onion sets. This application of the formalin solution disinfects the soil surrounding the seed and thus enables it to germinate and grow to the stage where it is beyond the attack of the fungus. The gains realized with this treatment in the past few seasons have been very encouraging to the onion grower.

The formaldehyde solution tanks and the drip attachment are easily adjusted to the seed drill, and these may be purchased of C. W. Genung of Madison, Ohio, and from other dealers in farm implements.

Home-made attachments may be made from empty syrup cans inverted, using a perforated rubber stopper in the outlet, connected by suitable rubber tubes with a drawn glass tube point at the end of each. This rubber tube will require a pinch cock to shut off the flow and the point will need to be set so that the solution falls with the seed before the earth covers it over. The profits from smut treatment where any disease exists are very great and for this reason the Experiment Station recommends it most strongly.

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